

The Blast Furnace and Steel Plant

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The Blast Furnace *and* Steel Plant

Vol. XV

PITTSBURGH, PA., JUNE, 1927

No. 6

"The Engine Was Working Beautifully"

remarked Captain Lindbergh to reporters, in describing the trans-Atlantic flight, which he accomplished with such masterly skill. In these remarks the aviator pays direct tribute to the ship, which he so ably piloted, and indirect tribute to those who designed and constructed it. No one appreciates more highly than Lindbergh, the service rendered by his monoplane, and it was his confidence in the machine that warranted the risk.

There are none who will hesitate to laud the daring of the flyer who made the perilous trip, but nevertheless the success which attended the venture was made possible by many others, whose names will never be mentioned. These unrecognized contributors are those engineers and scientists who have labored for years perfecting the engines and the materials of which aeroplanes are formed. Metallurgists in foundry and steel mill have developed metals of the finest grade for the engines and other parts, while scientists, for years, put their supreme efforts into the shaping of these metals, and elements, in order that they might produce a plane which would have the requisite endurance and stability under the most adverse conditions.

Working in relative obscurity, and frequently enduring hardships, these men must be given just recognition for the creation of a vehicle such as that which made Lindbergh a hero. The "Spirit of St. Louis," which became a reality in 1927, represents years of study and labor by men little known to the world.

Meeting of the Iron and Steel Institute

General Meeting Attended by Fifteen Hundred Members. Papers
and Addresses Deal with Subjects of Timely Interest.
Steel Industry on Sound Basis, says Gary

ON May 20, members of the American Iron and Steel Institute gathered at the Hotel Commodore in New York City to attend the 31st general meeting. The opening address was delivered by Elbert H. Gary, chairman, of the United States Steel Corporation who emphasized the strong position of the steel industry notwithstanding a recent falling off in the demand for the products of the mills. This slackening in demand he characterized as only temporary, but stated that the movement had been accompanied by a concurrent slight depression in prices. He deprecated the employment of unfair and tricky competition by same, and expressed the hope that such practices would be eliminated. The present administration was praised for its policy of "tending to its own business," and not imposing burdens on the conduct of business by others.

E. G. Grace, president of the Bethlehem Steel Corporation; James A. Campbell, president of the Youngstown Sheet and Tube Company; Willis L. King, vice president of the Jones & Laughlin Steel Corporation; John A. Topping, chairman of the Republic Iron & Steel Company, and Horace S. Wilkinson, president of the Crucible Steel Company were other speakers. These men stated that plant operation today averages about 80 per cent of capacity and that prospects for 1927 do not forecast as productive a year as was experienced in 1926.

The program for the day was as follows:

FORENOON SESSION, 10:00 A. M.

Address of the president, Elbert H. Gary, chairman, United States Steel Corporation, New York, N. Y.

"Application of Welding to a Steel Structure," J. H. Edwards, assistant chief engineer, American Bridge Company, New York, N. Y.

"Centrifugal Casting Processes," John D. Capron, research engineer, United States Cast Iron Pipe and Foundry Company, Burlington, N. J.

"The Operation of Large Hearth Furnaces Using 100 Per Cent High Volatile Coal," James E. Lose, superintendent Carrie Furnaces, Carnegie Steel Company, Rankin, Pa.

AFTERNOON SESSION, 2:00 P. M.

"The Pilger Tube Mill of the Pittsburgh Steel Products Company," W. C. Sutherland, general superintendent, Pittsburgh Steel Company, Monessen, Pa.

"The Theory of the Blast Furnace," Richard Franchot, Ferro-Chemicals, Inc., Washington, D. C.

"The Gas Permeability of Refractory Bricks Used in Metallurgical Furnaces," F. A. Wickerham, Central Research Bureau, Carnegie Steel Company, Pittsburgh, Pa.

Informal discussion under the Five-Minute Rule followed each paper.

BANQUET, 7:00 P. M.

After-dinner addresses on call of the president.

COMMITTEE ON ARRANGEMENTS

James A. Farrell, chairman; James A. Burden, E. A. S. Clarke, Eugene G. Grace, Charles M. Schwab, John A. Topping.

The first paper, delivered by Mr. Edwards, dealt with the fabrication of structural material by welding. A five story building recently erected by the Westinghouse Electric & Mfg. Company at Sharon, Pa., was cited as an example of an achievement in construction by welding. Illustrations make apparent, the diversity of application of this method of uniting shapes of various form. Costs indicate a saving over the use of rivets.

"Centrifugal Casting Processes" by John D. Capron, which was the second paper on the program contained a historical review of this manner of casting together with a description of those processes now in service. Much interest was manifest in this paper as the subject is one which is being discussed by open hearth operators in relation to the casting of steel ingots. Especial attention was given the deLavaud process of casting as eight companies are operating under licenses under deLavaud patents.

James E. Lose, presented the third paper in which he discussed "The operation of large hearth furnaces using coke made from 100 per cent high volatile coal." In view of the fact that our choice of coal is being gradually restricted this paper is most pertinent. Mr. Lose mentions the increase in hearth dimensions of furnaces of the present day and the changes in operation brought about by these modifications in design.

The afternoon was opened by a description of "The Pilger Tube Mill of the Pittsburgh Steel Products Company." Mr. Sutherland, general superintendent of this company, described the manufacture of tubes in the Pilger mill and presented illustrations to show the successive stages of manufacture. As there are several steel companies considering the installation of tube mills, much interest was evinced in Mr. Sutherland's description.

"The Theory of the Blast Furnace," by Richard Franchot, was devoted largely to a discussion of the thermal conditions which obtain in the modern furnace. The paper was divided into two sections, the second dealing with the "Disposition of Hearth Heat."

In closing the technical session, Mr. F. A. Wickerham gave consideration to the "Gas Permeability of Refractory Brick Used in Metallurgical Furnaces." Mr. Wickerham's information was secured from the research bureau, of the Carnegie Steel Company in which department he is an assistant. The treatment of the subject is thorough and comprehensive.

On the following pages of this issue several of the papers delivered are reprinted. Others will appear in the July issue.

*The Pilger Mill of the Pittsburgh Steel Products Company**

Description of a Recent Installation of a Mannesman Pilger Mill
Used in the Manufacture of Seamless Tube of Extra-
ordinary Large Diameters and Lengths

By W. C. SUTHERLAND†

WITHIN the past few years many improvements have been made in the methods used to extract oil from the ground, and probably one of the most important of these has been the development of rotary drilling, by means of which it has become possible to descend to depths only dreamed of before, so that nowadays drilling to a depth of a mile and a quarter and a mile and a half in quest of oil is the rule rather than the exception in a large part of the oil producing districts of the world.

With the advent of this deep drilling came the need for stronger pipe, both for the drilling operation itself and for casing and tubing. Welded pipe had long been the only kind in suitable sizes available, but the new requirements demonstrated that at a suitable size and weight welded pipe did not have the desired and necessary strength for the severe strains to which it had to be put. The very nature of its manufacture required soft weldable material, therefore stronger welded pipe could only be obtained by increasing the wall thickness, and this could only be done within well refined tolerances, inasmuch as a large portion of the pipe must be capable of telescoping with other pipe in the natural process of drilling and casing a well.

It being a well-known fact that seamless tubing could be successfully made from practically any grade of good quality steel, oil producers turned their attention to the seamless tube industry for a solution of their problem. The latter recognized the fact that there was a demand for a high class product in a heretofore unsuspected field, but it also found itself unprepared; the demand was for large pipe as well as small pipe and about the largest size of seamless tube which had been made up to that time, in the United States, was of 8 in. diameter.

The largest size which the Pittsburgh Steel Products Company had ever made was of 7-in. diameter and the oil industry was demanding seamless pipe up to and even beyond 13-in. Only a few of the American seamless mills were equipped to produce as large as 8-in. pipe by the established automatic rolling mill method, and at that time the possible length that could be reached was barely 30 ft. Almost simultaneously with the inquiry for seamless pipe and casing came the inquiry for longer lengths up to 46 ft.

The officers of the Pittsburgh Steel Products Company promptly instituted a thorough study, both in this country and abroad, of the various processes of making large seamless pipe in lengths as long as the

trade might ask for and decided that the Mannesmann Pilger process offered the most advantages, inasmuch as by this process, large diameter pipe, true to size and gauge in extra long lengths, could be produced direct from the ingot, and the product would have a uniformly good finish.

This investigation resulted in the purchase of one of the most modern Mannesmann Pilger mills obtainable in Europe. Many parts of this new equipment were especially designed for this particular installation which is capable of producing pipe from 6 to 12 in. in diameter.

This new seamless tube manufacturing plant was purchased complete, as a unit, including the electrical, hydraulic and pneumatic equipment and was erected at the Allenport Works of the Company at Allenport, Pa., in 1926, starting production in September of that year, being the first mill of this size and type to be installed and operated in America.

Probably one of the most important features in connection with this mill is its ability to pierce and form tubing directly from the cast ingot, thus eliminating the usual rolling processes between the ingot and the piercing mill.

The ingots used are round, of a diameter and weight to suit the tubing to be made, and are regularly poured by bottom casting. The steel must be carefully made to insure the quality in the finished product that is so necessary in tubing subjected to the severe tests that oil country tubing has to withstand.

Almost equally important is the ability of this mill to roll extremely long length; for instance, there is now at this mill an 8 $\frac{5}{8}$ -in. tube 131 ft. long. A tube of this length has no real commercial value, due to transportation difficulties, but illustrates what can be done on long-length tubing manufactured in a Pilger mill.

It is optional in the operation of the Pilger mill whether you break the ingots in two or roll the whole ingot in one long tube and cut to length afterwards. The latter procedure is generally followed, because there is a saving in material resulting from the production of less scrap by eliminating single-length rolling where crop ends must be wasted from each end of each tube.

If the ingots are to be broken, a rather unique method is employed to get the exact length or weight in each part. By this method the ingot is nicked on two sides by tools applied by a hydraulic ram; the nicking tools are then automatically removed and the ram, continuing forward, forces the ingot against a "V"-shaped block and breaks it at the nicked places. This fracture affords an excellent opportunity for inspection of the steel in the ingot.

*Paper read before the American Iron and Steel Institute, New York, May 20, 1927.

†General Superintendent, Pittsburgh Steel Company, Monessen, Pa.

Electric magnets on overhead cranes are employed for handling ingots in the storage yard and to the platform of the heating furnaces.

Two continuous furnaces, 70 ft. long by 10 ft. wide, and fired with natural gas, are employed for heating the blanks preparatory to piercing. The bottom of these furnaces are inclined sufficiently for the blanks to roll forward, mainly by gravity, towards the discharge end. The furnace bottom declines sharply at the point of discharge, permitting the heated blank to roll out onto a roll conveyor and thence to the entrance trough of the piercing mill. Two furnaces are necessary in order to keep the mill supplied with properly heated blanks, taken from the furnaces alternately.

The piercing mill is of the Mannesmann, or roll type, and is of extremely heavy and rugged design. The working rolls are 23 in. in diameter and the top and bottom guides are rollers 12 in. in diameter. All adjustments on this mill are made by the use of motors driving through gear or worm reductions. This mill is driven by a 2,250 hp. a.c. motor. Inasmuch as the process of piercing billets on this type of mill

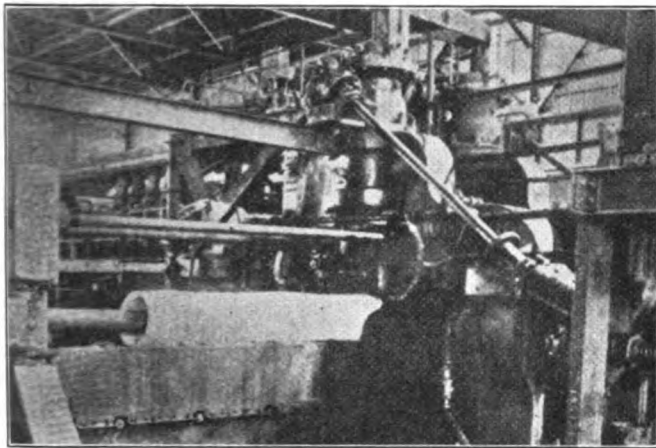


FIG. 1—Pierced ingot leaving piercing mill.

is quite generally understood, a detailed description of this operation is not considered necessary.

The pierced ingot presents the appearance of a short, rough tube with extremely heavy walls, as it leaves the piercing mill. (See Fig. 1) Without further heating it travels onto a conveyor which places it in the trough in front of one of the two Pilger mills.

At this point, a mandrel, which consists of a 10-ft. bar of round steel, is inserted into the hollow blank. (See Fig. 2) This mandrel is of the diameter it is desired to make the inside diameter of the tube, and is carried on the forward end of a plunger working in a pneumatic cylinder, which in turn is moved by two large hydraulic cylinders which, by connecting to the pneumatic cylinder, form a hydraulic ram which moves slowly but steadily forward, pushing the mandrel through the pierced blank and supporting it in the actual rolling operation.

The Pilger mill, while having rolls with parallel axes mounted and operated as in an ordinary rolling mill, differs from the latter in that the process is one of forging or kneading rather than rolling, as the term rolling is generally understood. The rolls are so designed that the pass is cut away through half of the circumference (see Fig. 3) with the result that with

each revolution, the portion not cut away strikes the tube a definite and severe blow and due to the fact that the direction of rolling or rotation of the rolls is against the tube, rather than with it, as is the case

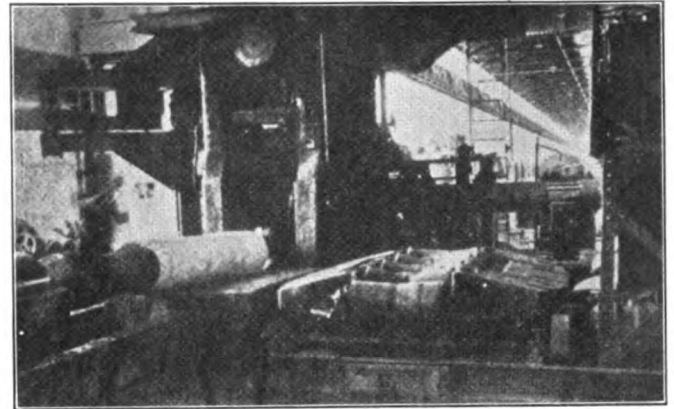


FIG. 2—Pilger mill, showing pierced ingot on mandrel.

in ordinary rolling, the tube is thrown back while in working contact with the rolls.

The forging action of the rolls driving the tube backward causes the air to compress in the pneumatic cylinder, but as the rolls revolve and again bring their cut away section into the tube space, this compressed air forces the plunger, carrying the mandrel and tube, forward again for the next stroke of the rolls. Thus the air acts as a spring, taking up the effect of the blows, but continually forcing the tube forward for the succeeding blows. A mechanical device automatically rotates the mandrel and tube 90 deg. between each forging blow of the rolls.

The tube thus progresses through the rolls, coming out at the opposite side of the mill a practically finished tube insofar as size and wall thickness are concerned, although purposely left slightly oversize.

The mechanical stripping device on the roll housing is then brought into play which holds the tube in a stationary position while the mandrel is withdrawn by the hydraulic cylinders, which during the

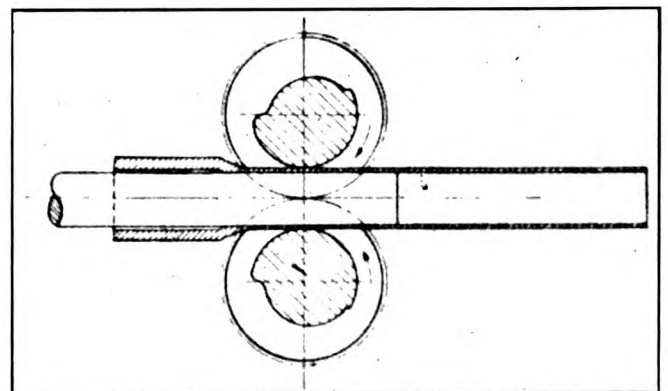


FIG. 3—Design of rolls for pilger mill.

forging operation had been forcing the tube forward. When the mandrel is free it is removed from the holder and allowed to cool in the air for a few minutes and then dropped into a tank of water to cool off, and another mandrel is placed on the end of the plunger, ready for the next tube. Generally there are five mandrels in use successively, three cooling in the air, one in water, and one working in the mill.

Meanwhile the tube is conveyed beyond the rolls to a hot saw, where the crop ends are cut off and the rolled blank cut into two or three lengths. As mentioned, previously, there are two Pilger mills in the installation, which alternately take the hollow blank from the piercing mill. These two mills are set in line and are driven by a 2,000 hp., d.c. motor on the shaft of which is a 60-ton, 28-ft. diameter fly wheel. Further, the rolls are so machined and coupled up to the mill that they strike their forging blows at alternate intervals thus keeping the working load on the motor distributed.

Leaving the hot saw, the tube is conveyed across a transfer table to a central set of conveyor rolls, whence it is conveyed lengthwise into, and at one side of, a reheating furnace. This furnace is fired with natural gas and is long enough to accommodate a tube 50 ft. in length. It is equipped with two trains of nichrome rolls mounted on water-cooled shafts working in roller bearings, one train at either side, on which the tube is admitted to and discharged from the furnace.

The tube rolls slowly across the floor of the furnace to the opposite side, sufficient time being allowed in its passage to bring it up to a satisfactory annealing temperature. Reaching the other side it travels out through the discharge door onto a roller conveyor which carries it to the sizing mill.

At this point, the mill equipment is so arranged that if desirable or necessary, the tube can be mechanically lifted to another conveyor and passed through a reeling or polishing mill, then returned to the former conveyor at another point from where it continues through the sizing mill and cross rolls and onto the cooling rack.

If reeling is not essential, this operation is omitted, the tube passing straight from the reheating furnace through the sizing mill, which consists of two horizontal rolls grooved to form a perfect round of the exact desired outside diameter of the tube. The tube being finished slightly oversize in the Pilger mill as stated above, the sizing rolls compress it to an exact diameter and elongate it. No mandrel is used in this operation. The sizing operation also serves to crack and loosen the scale formed on the inside of the tube as a result of the reheating operation, which scale is later blown out with compressed air.

The reeling or polishing operation is used only when a small quantity of an odd size of product is wanted, an amount not sufficient to warrant the expense of dressing special rolls, or the loss of production that would result from changing rolls in the Pilger mill. This machine consists of a pair of short heavy rolls of special design which are set side by side in a special heavy housing. Their axes are slightly inclined to the horizontal and in opposite directions, crossing each other at a corresponding angle in the middle of their length. A mandrel is pushed into the space between the rolls and the hot tube is rolled over the mandrel. Both rolls revolving in the same direction, start the tube and mandrel revolving also, and due to the inclination of the rolls the tube is slowly drawn over the mandrel, leaving the mill practically straight and perfectly round but larger in diameter and thinner in wall section in proportion to the pressure applied by the working rolls.

Leaving the sizing mill the tube is conveyed to and passes through a pair of cross rolls or a hot

straightener, after which it is commercially straight as it is discharged onto the cooling rack. The cross rolls machine is of the standard type usually employed in the lap-weld industry and need not be described here.

From the cross rolls, the tube is mechanically lifted onto a long inclined cooling-rack, across which it is slowly conveyed by means of endless chains.

A very important adjunct to the successful and economical operation of this Pilger mill unit is the equipment for reclaiming the mandrels used in forging the tubes. This equipment consists of a heating furnace, a hydraulic upsetter and a specially designed reeling machine. By means of this outfit, mandrels which have been reduced in diameter by wear in service, are heated, placed in the upsetter and stoved to a larger diameter, then passed back and forth through the reeling machine until they are brought back to their normal size.

Equally as important is a special roll lathe for redressing the peculiarly shaped Pilger mill rolls. The machine is largely automatic and works on both rolls of a pair simultaneously.

Included in the equipment of this Pilger mill installation are complete hydraulic and compressed air systems entirely independent and separate from the rest of the plant.

The entire mill is electrically driven with power supplied from the company's central power plant at Allenport, and the electrical equipment includes 152 motors, totaling 10,000 hp.

The entire group of buildings, assembled as one, is served by overhead electric cranes, eight in number, ranging in capacity from $7\frac{1}{2}$ to 20 tons and in span from 63 to 118 ft.

All of the original mill equipment came from abroad and with it was included sufficient spare parts and such accessories as rolls, mandrels, piercing points, etc., to insure continuous operations. Bearing in mind that the actual working tools on this Pilger mill are subjected to conditions unlike those in the regular rolling mill, it was natural to assume that some development work would be necessary before satisfactory replacements could be secured from American sources. As this condition has now existed for several months, we are in a position to say that, in the case of most of the supplies, domestic replacements are proving equal, and in some instances superior, to the European material.

The arrangement in the construction and installation of this mill was so planned that the material would move continuously in one direction to the finishing department. The finishing department is also laid out with a view to automatically conveying the material from one stage to another in the finishing operations, so that when finished complete it has been delivered to the loading track or shipping point. (See Fig. 4.)

The tubes are sufficiently cold by the time they reach the end of the cooling-rack in the finishing department to be given a preliminary inspection. They are also commercially straight, as they have been kept turning as they were cooling; but as the requirements for straightness on oil country tubular products are severe, all tubes are taken to a straightening press where any irregularity in this regard is corrected.

All equipment in the finishing department for subsequent operations and handling is of domestic

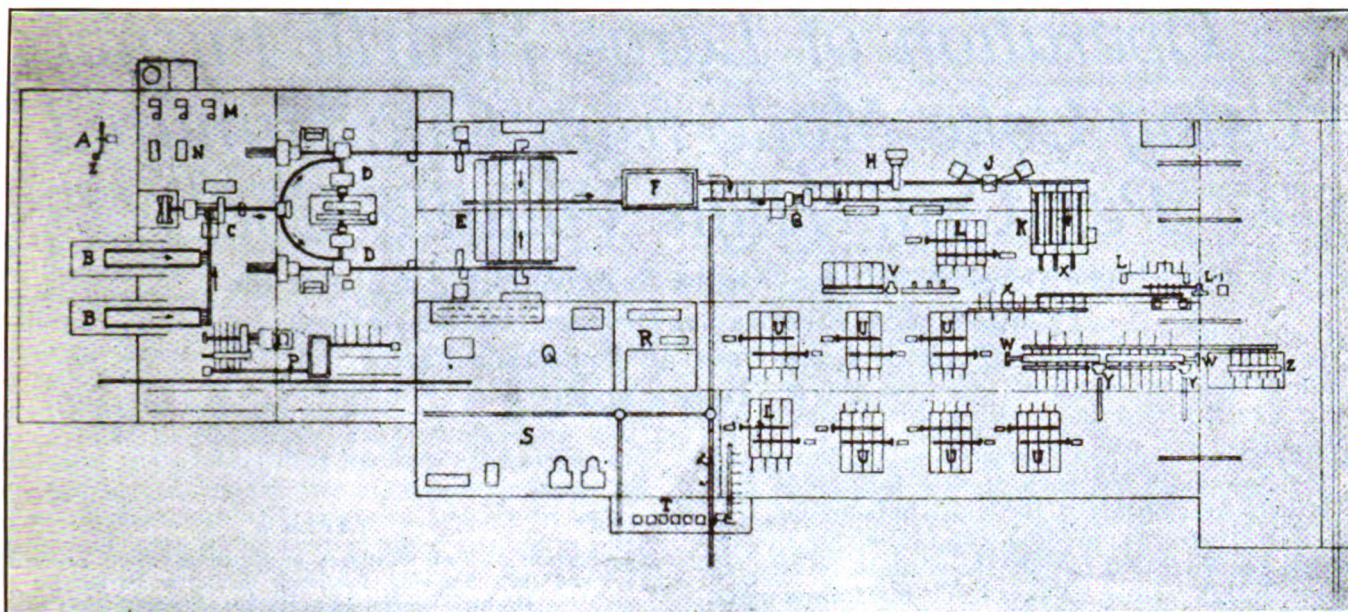


FIG. 4—Lay-out of the Pilger Mill Plant, Allenport.

Key—(A) ingot breaker; (B) ingot seating furnace; (C) piercing mill; (D) pilger mill; (E) transfer table; (F) reheating furnace; (G) reeling machine; (H) sizing machine; (J) cross rolling machine; (K) cooling table; (L) cut-off machines; (L-I) flattening press; (M) hydraulic pumps; (N) air compressors; (P) mantrel reclaiming machine; (Q) electric sub-station; (R) roll shop and tool room; (S) coupler and thread protector department; (T) galvanizing department; (U) threading machine; (V) straightening press; (W) hydraulic testing machine; (X) inspection tables; (Y) screwing-on machines; (Z) scales.

make and a large part of it was specially designed and built for this particular installation, an undertaking in which the company's engineers figured pre-dominatingly.

From the final straightening the tubes are taken to the cut-off machines where the rough ends left from the hot saw cut just behind the Pilger mill are cut off and the clean end reamed and chamfered at the same time. The cut-off machines are of the lathe type and are either built to receive and eject the tubes mechanically or are provided with mechanical tables which provide a means of using electric power for all the handling of the tubes. In connection with the cut-off machines, there is a powerful flattening press in which each and every crop end is flattened to determine whether or not the material is sufficiently ductile.

From the cut-off machines, the tubes are conveyed to the inspection tables, at which time, in addition to being thoroughly inspected, the loosened scale is blown out by compressed air and the tube is drifted. (This term applies to the passing of a drift or plug of certain specified dimensions through the tube to ascertain whether the inside diameter is of proper size to allow the telescoping of smaller sizes.)

The tubes are next conveyed to the threading machines. These machines are set up in pairs in the conventional manner for threading pipe and are all equipped with mechanical tables for handling the tubes to and from the machines. As the thread is completed on each end of a piece of pipe, it is inspected and gauged and, if defective in any way, is cut off and rethreaded right at that point. If the threading passes the inspection, a coupling is put on one end and a thread protector on the other, and the tube is taken to the coupling screwing-on machine where the coupling is screwed on machine-tight.

The tubes are next mechanically transferred to the hydrostatic testing machines and subjected to

the specified test. These hydrostatic testing machines, of which there are two, are very large and rugged, capable of testing tubes of any diameter up to 14 in. by 46 ft. long to a pressure of 2,500 lbs. per sq. in. Each testing machine receives its hydraulic power from an individual pump on the line of which is an accumulator adjustable to various pressures by the addition or dropping of weights.

From the testing operation the tubes are conveyed to the shipping bay and in this move are passed through an oiling or coating machine, then onto a skid table to dry, after which each is weighed, measured, stenciled, and stamped, and dropped into a set of bucks. When a crane load has accumulated, it is picked up and loaded into railroad cars spotted in the building on a depressed track.

Other auxiliary machinery and equipment is provided for boring, tapping and galvanizing the necessary couplings for all sizes of tubes made on this Pilger mill as well as for forming and tapping the thread protectors. The blanks for each of these articles are cut from stock rolled especially for them on the mill.

The Mannesmann Pilger mill installation of the Pittsburgh Steel Products Company is complete in every detail and is a tube mill capable of producing tubes from 6 to 12 in. in diameter by 46 ft. long or even much longer for special cases. It starts with charging a cast round ingot in the heating furnace and loads out a finished, threaded and coupled tube on the shipping track, having produced all parts and performed all operations to finish all parts that enter into the make-up of the finished product.

The heaviest tubes produced to date were 11¾ in. outside diameter by 32 ft. long with 1⅛ in. wall, each of which weighed approximately 4,400 lbs.

The nominal capacity of the mill is about 300 tons per day.

The Operation of Large Hearth Furnaces Using Coke Made from One Hundred Per Cent High Volatile Coal*

The Development and Present Features of Operation of the Large Hearth Furnace are Discussed by the Author.

Type of Coke Used an Important Factor

By JAMES E. LOSE†

THE increase in blast furnace output during the past few years has been of such magnitude that it may be considered the most outstanding feature of their recent development. Analysis of the cause of the increased output shows it to be the result of several factors. One of the most prominent has been the general installation of large hearth furnaces, which have proven beyond doubt their ability to make more iron of equal or better quality, with no more and usually with less coke per ton of iron than is possible with smaller hearth furnaces.

Another factor of equal effect upon the tonnage increase has been the tendency to drive the furnace to the upper limit of wind capacity, consistent with, and in some cases in spite of, the economic relation between increased furnace loss and decreased cost above. Several reasons are to be found for this development. One is the new installation of single furnace plants built during periods of excessively high construction costs. Such furnaces are usually operated on picked raw materials and are pushed to the upper limits of capacity in order to reduce the per ton cost of interest on the extremely heavy investments they represent. The high tonnages produced by these plants became an incentive for other furnace operators to reach higher outputs and resulted in a spirited competition between plants. Also, as the large hearth furnaces are built in increasing numbers at different plants, it was found that what was formerly considered the upper limit of wind capacity no longer held true and that a considerable increase could be made in the wind blown, and consequently higher production realized with little detriment to other features of operation.

These conditions have resulted in a nearer approach to maximum possible production than ever before realized. A clear example of this is seen in Table A, a comparison of a year's operation of two furnaces of equal size, Furnaces No. 6 and E, located at the South Chicago Plant of the Illinois Steel Company. The performances given are for the year 1919 for No. 6 Furnace, and for the year 1926 for E Furnace. The comparison shows E Furnace to have produced 121.6 tons more iron per day, and that it was blown with 15.9 per cent more wind per minute. This comparison is an indication of the results being obtained in the very recent campaign for higher tonnages, and shows that the full possibilities of the large

hearth furnaces were not realized for some years after they were developed.

TABLE A

Comparison of Two Furnaces of Equal Size for Years 1919 and 1926, Showing Tendency in Latter Period for Higher Winds and Higher Production

	No. 6 Furnace	E Furnace
Diameter of Hearth	20' 9"	20' 9"
Average daily production, tons	600	721.6
Total ore, cinder, scale, etc.	4661	4235
Gross coke, lbs. per ton	1972	1877
Limestone, lbs. per ton	673	801
Net coke, lbs. per ton	1972	1871
Scrap used over produced, lbs. per ton	—48	+7
Flue dust produced, lbs. per ton	257	265
Flue dust used	159	250
Mesaba ore, per cent used	100.00	74.7
Cubic feet of wind per minute	44726	51860
Temperature of blast, deg. F.	1114	1201
Actual yield of metallic mixture	48.91	52.7

The development of the blast furnace hearth, credit for which rests with the Edgar Thomson Plant of the Carnegie Steel Company, and later with the South Chicago Plant of the Illinois Steel Company, dates back over two decades.

No discussion of the present features of operation is complete without some history of the development, including an analysis of the operating difficulties and the steps taken to overcome them.

Starting with a hearth size of 14 ft. in a furnace of about 22 ft. bosh, the hearth was steadily increased during the first 10 years to about 18 ft. with no appreciable increase in the bosh or other sections of the furnace. This change resulted in a gradual steepening of the bosh angle, and a lowering of the bosh height.

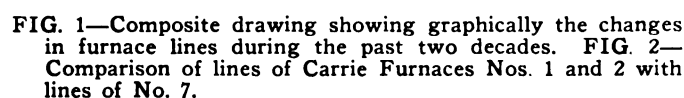
During the second period of development, the bosh was also increased in size, but to a lesser extent than the hearth. The second phase included no further steepening of the bosh angle and therefore resulted in still lower bosh heights. An additional effect of the second development was an increase of the in-wall batter caused by the larger bosh. In analyzing this gradual change of hearth size with its resultant changes in other dimensions of the furnace, we find that it had for its incentive certain very logical reasons. The small-hearth, flat-bosh furnaces had given good results with hard ores, but were unsuccessful with the gradually increasing percentage of Mesaba ore. Irregular working, checking and slipping, coupled with poor quality of iron, high coke consumption and low production, was the rule rather than the exception during this period. Inability to

*Paper read before the American Iron and Steel Institute, New York, May 20, 1927.

†Superintendent, Carrie Furnace, Carnegie Steel Company, Rankin, Pa.

In order to properly serve the increased demands of the larger furnaces, it was necessary to rebuild or remodel practically all of the furnace auxiliaries,

The existing stoves were of the large checker, three-pass type, 21 × 90 ft. in size. They were raised 20 ft., relined with 4½ in. square checker openings, and equipped with pressure burners, attaining a capacity of 1,300 deg. F. straight line heat with a wind volume of 50,000 cu. ft. per minute. To meet the requirements of the small checker stoves it became necessary to install gas washers. Feld type washers were adopted for this purpose because of their ability to wash the gas well enough (1) to eliminate the deposition of sludge in the mains and the consequent



The existing bins were of the Brown parabolic type, having intermittently located doors operated by steam cylinders at one group of furnaces and electrically operated doors at the other. Two larry cars and five men per turn were required to fill each 500-ton furnace. The parabolic features of these bins were retained and the Brown doors were replaced by continuous hand operated doors. Modern two-pocket larry cars equipped with indicating and recording scales were installed. A unique feature of the stock house is that by the adoption of interlocking electrical controls of skip and bells, the installation of large skip cars with high speed hoists, the use of automatic skips to remove the coke braise, automatic gauge rods to test furnace, electrically operated grizzly type coke screens, and the judicious location of controls, it is possible to do all the labor incident to filling a 700-

ton furnace with ore, coke, and limestone with a force of one man. The duties of the single operator are not at all excessive and it is felt that no additional men will be required up to the capacity of a 900-ton furnace.

Fig. 3 shows an arrangement of this stock house. The controls for operating the skip cars and coke screens are located on a board at the skip hole just in front of the larryman. The bells are electrically interlocked with the skips and operate in their proper sequence with no attention from the larryman other than the running of the skips. The skips are filled with coke by operating the control of the grizzly screens; the coke braise produced is removed by a small automatic skip which is electrically interlocked with the main bell and makes a round trip every time the main bell is dumped. The usual skip operator is thus eliminated. No man is necessary to poke down the ore either from the top of the bins or from a platform below.

The design of the furnace proper includes the accepted type of hearth and bosh construction consisting of a deep cast iron hearth jacket, a steel plate tuyere jacket with inserted cooling plates, and alternate bosh bands and rows of bosh cooling-plates. No cooling of the brickwork above the mantle is done, as it is felt that with proper distribution of raw materials and sufficient thickness of lining none will be required.

The stock line is protected by L-shaped annealed steel casting plates set in the brickwork, this type of construction having given good service at several plants. The distributing mechanism at the furnace top combines the features of good stationary distribution and of the McKee rotating top.

Filling of the furnace is usually done in the following manner:

1 skip ore
1 skip coke
1 skip ore
1 skip stone
1 skip coke

} dump large bell.

Coke unit 9000 pounds to 12,000 pounds.

This method embodies the features of stratified filling the advantages of which were pointed out in Mr. George W. Vreeland's paper* on "The Distribution of Raw Materials in the Blast Furnace," and in Mr. J. A. Mohr's paper† on "Methods of Charging Raw Materials into the Blast Furnace." Other fillings are used at times as the furnace conditions dictate.

The raw materials used are as follows: Ore—Mesaba 90 per cent; Old Range 10 per cent; limestone is of average quality containing 2 per cent silica and 50 per cent available lime. The coke is made at the Clairton Coke Works from 100 per cent high volatile Klondike coals, and while much credit must be given to this plant for their marked success in producing the existing quality of metallurgical coke from an admittedly poor grade of raw material, nevertheless the coke is inferior to that produced by ovens using a mixture of high and low volatile coals. The feature of cost, however, does not permit the use of low volatile coals at this plant and it becomes necessary for the furnace operator to use every means at

*Yearbook, American Iron and Steel Institute, 1916, p. 106 sq.

[†]Yearbook, American Iron and Steel Institute, 1919, p. 231 sq.

his disposal to compensate for the deficiencies existing in coke quality.

Coke, from both physical and chemical standpoints, has long been recognized as the most important raw material in its effect upon furnace operation. The importance of the coke in maintaining the permeability of the stock column has increased with the general replacement of hard ores by the soft and fine Mesaba ores. It is natural, therefore, that an analysis of any furnace operation cannot be made without full knowledge of the physical and chemical properties of the coke used in that operation.

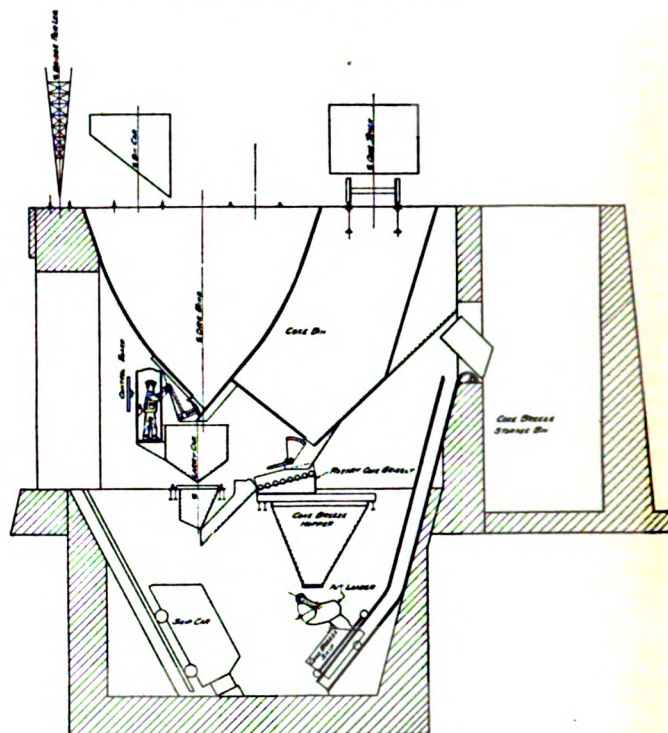


FIG. 3—Arrangement of stock house at Carrie Furnaces Nos. 6 and 7.

A description of the characteristic features of the coke made at the Clairton plant follows: Clairton coke, by which name it will be referred to, is of considerably smaller size than coke made from a mixture of high and low volatile coals; it also contains more cross fractures, which cause it to break more in handling. As a result, even though the coke is well screened at the coke plant, it contains considerable fines by the time it reaches the furnaces, and must be screened again to remove the fines before charging. Following is an average analysis of Clairton coke received at Carrie Furnaces during the year 1926.

ANALYSIS OF CLAIRTON COKE

Ash	Sul.	Phos.	Vol. M.	Fixed C.	SiO ₂ In Ash
11.12	1.01	0.013	1.02	86.88	5.61

The fixed carbon is relatively low, and as an increased part of the carbon must be used to melt the higher ash contained, still less of the fixed carbon is available for the melting of the gangue in the rest of the burden. As a result, the silica content of the ores used must be kept low to prevent excessively high slag volumes, thus reducing the percentage of high silica ores that can be used without adversely affecting economy of operation.

The need of intensive screening of the coke at the furnace is further emphasized by the fact that the dust screened out is of very poor quality chemically, as may be seen from the following analysis:

Ash	Sul.	Fixed Carbon	SiO ₂ in Ash
19.10	1.05	77.67	10.00

The removal of such an inferior part of the coke from both a chemical and physical standpoint effects a decided improvement of the coke as a furnace fuel. The effect of the high percentage of ash and other constituents of the Clairton coke will be discussed more in detail in the following analysis of furnace operation.

Operation of the Furnace

As noted in the foregoing description of the furnaces and auxiliaries, the furnaces are amply provided for in all of their requirements as to heat, wind, filling, distribution, etc. Their lines are almost identical with furnaces of similar size operating, coke excepted, on very similar raw materials. Therefore, it may be assumed that any deficiencies occurring in the operation of the furnaces are due either to the difference in coke quality or to the method of operation. All of the iron produced is basic pig iron and in the operation it is endeavored to maintain the silica content of the iron at its proper low limit by increasing the burden rather than by increasing the basicity of the slag. This method is generally recognized as the most economical in coke and the most productive in quantity of iron. The slag is kept as lean as possible, consistent with proper desulphurization of the iron, thereby achieving the economies resulting from the lower fusion temperature and greater fluidity of the slag in the furnace bosh. The benefits of high blast temperatures are recognized, and every effort is made to gain the advantage in coke economy, better desulphurization, and higher production resulting from the use of higher blast temperatures. The amount of wind blown is carried to the very upper limit consistent with furnace loss, coke economy, and regular driving of the furnace.

Regularity in the movement of the furnace is of first importance in this operation, for with fine Mesaba ores, checking and rolling result in a large production of flue dust. A lighter burden than desired is then carried down to the bosh, the furnace becomes hot, and the silicon content of the iron increases. Due to the higher silicon content of the iron and to the fact that the high production of flue dust has carried much silica out of the burden which would normally reach the tuyeres, the furnace becomes limey, and forces the lowering of the blast temperature and generally deranges the operation for a period of several days.

Operations such as are described above are in marked contrast to those where hard ores are used and where it is possible to blow extremely high wind even though high pressures and checking result. Such irregularity of operation has little effect upon the production of flue dust from hard ores, due to the increased permeability of the charge and to the fact that but little of the ore is carried out of the furnace. The Trumbull furnace operation of several years ago was a characteristic example of this type of operation. Very high wind was blown, the blast pressure ranged from 18 lbs. to 25 lbs. and the furnace checked practically continuously, yet due to the use of hard ores the operator was able to maintain

high production with low flue dust loss, excellent coke practice, and good quality of iron.

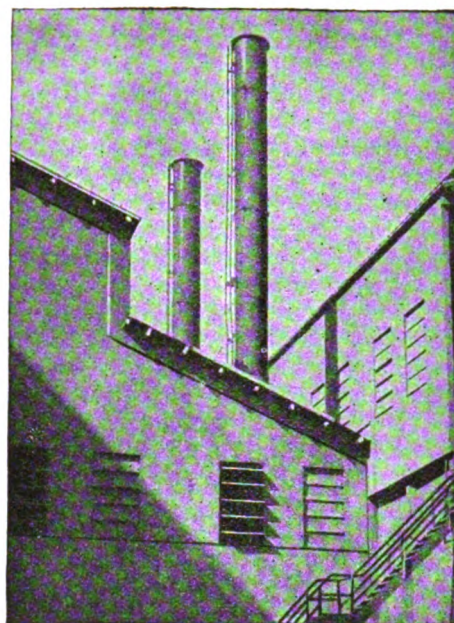
(To be continued)

Increasing Life of Metal Smoke Stacks

Welding is gaining more and more in popularity as a method of constructing smoke stacks. Because the brick required in erecting a smoke stack is more expensive than the metal needed for the same purpose, and because the actual construction of a brick stack takes a greater amount of time and skill, the metal stack is looked upon with increasing favor.

The only drawback has been the shorter life of the metal stack, particularly where the flue gases are corrosive. The use of corrosion-resisting plate is not entirely effective if seams collect acid-bearing dust, and hence are subject to more rapid corrosion than the rest of the plate.

With these points in mind, the engineers of a large Portland cement plant decided to construct two new stacks of copper-bearing steel plate (known to be excellent in its resistance to atmospheric rusting) with oxwelded joints.



All-welded smoke stacks

The two stacks were to be 61 ft. 1 in. high, with an inside diameter of 3 ft. 6 in., each requiring 10 sheets of copper-bearing steel plate. These sheets, ½ in. by 6 ft. 13⁄8 in. by 11 ft., were rolled and the longitudinal seams welded, forming rings which were then welded together in the shop. When the 10 sections had been joined, the entire stack was raised in position with a gin pole.

These two stacks were completed by a welder and one helper in 189 hours' working time. The entire shop cost, including the 20 pieces of plate, the handling and rolling of the sheet in the shop, welding gases, rod and all miscellaneous expenses, showed an important saving, since a brick smoke stack would have cost approximately four times as much and could not be built in twice the time.

The Theory of the Blast Furnace*

The Author Critically Reviews Two Theories Commonly
Advanced to Explain the Low Efficiency of the
Blast-Furnace as an Iron Producer

By RICHARD FRANCHOT†

I. The Blast Furnace as Gas Producer

WHEN, in 1904, Johnson explained the hot blast, he bridged a gap between practice and theory that had existed for over 70 years. Gayley's dry blast practice very soon lined up with Johnson's theory. The fact that it is much cheaper to add heat to the blast than to take moisture out of it puts no cloud upon the title of the theory to a big share of the truth about the blast furnace. Today, we may well regard as proven the proposition that coke consumption, burden ratio, or operating efficiency is limited and determined by the heat relations existing at the extremely high temperature which is maintained in the hearth. Practice is now going along hand in hand with theory in enlarging the hearth, thereby increasing furnace productivity and somewhat improving fuel economy.

It is to be expected that with growth of knowledge theory instead of lagging behind will lead practice along the path of progress. An attempt to correlate the two would therefore seem to be in order. What is and always should be asked is the question: what limits efficiency? Why is coke consumption not smaller or production larger? The answer should tell whether efficiency can be improved and, if so, how. Desirability of improvement may then become a live question. At present there seems to be but little choice in the matter. The introduction of the of this outstanding fact. The textbooks of iron metallurgical advance. Today, with the highest blast heats, the furnace is as yet less than 40 per cent efficient in iron smelting. It is usually more than 40 per cent efficient in gas producing.¹

Practice, then, would seem to be very much in need of a theory to account for the fact that the furnace is as a rule a better gas producer than iron smelter. Strangely enough, there is not to be found in the literature any generally accepted explanation of this outstanding fact. The textbooks of iron metallurgy do not even offer a comprehensive hypothesis purporting to show why, in coke practice, not less than 60 per cent of the coke carbon, often more than 70 per cent, leaves the furnace as CO. The lack of a clear, definite, adequate estimate of the causes underlying fuel economy is probably closely related to the fact that modern American practice shows, on the average, no better efficiency than that of Lowthian Bell in the Cleveland District, England, two generations ago. A great advance has been made in mechanical methods, accomplishing a ten-fold increase of productive capacity. Metallurgical methods have not changed in 100 years.

There is no mystery in the functions of the smelting process. Iron has to be reduced from its oxides, melted and separated from the ore gangue by fluxing

the latter with lime. At the same time the coke ash has to be fluxed; the coke sulphur kept out of the iron; and the desired amounts of silicon and other minor constituents have to be reduced and put into the pig. There is a quite definitely known amount of heat or energy absorbed in each of these items of work. The heat is generated by burning carbon and preheated air, forming CO, which in being oxidized to CO₂ develops energy absorbed in reduction. The heat and energy supplied by carbon and heated air in the proportions required for CO formation are well known quantities. Hence there is a definite quantitative relation between the heat plus energy value of a unit of carbon and the heat and energy actually absorbed in producing a unit of pig iron with its accompanying slag. On examining this relation, it is seen that the reaction between hematite and carbon monoxide, in which the energy developed in the oxidation of 3CO to 3CO₂ is a little greater than that absorbed in the reduction of Fe₂O₃ to 2Fe, involves a ratio of iron to carbon by weight of 1:0.321. In other words, the oxidation of a pound of carbon from CO to CO₂ develops somewhat more heat than that absorbed in iron reduction for 3.30 lbs. of a 94 per cent pig. It is further seen that in CO formation by air with blast at 1,200 deg. F. (649 deg. C.) and five grains moisture, a pound of carbon develops a quantity of heat (3,160 lb.-cal. or centigrade units) equal to that absorbed in the production of 3.95 lbs. pig, at 800 lb.-cal. per pound.

In view of the well balanced relation between the heat and energy value of coke and air on the one hand and the heating and reducing work of the smelting process on the other, the reasons for limiting the burden to that which can absorb less than 40 per cent of the coke energy would seem to be well worth finding. If the smelting work could be brought up to 50 per cent of the coke energy, it would probably mean a 25 per cent increased production with little increase of operating expense except for ore and stone. The reasons for the present limitation to under 40 per cent would doubtless be still clouded in mystery were it not for the light shed upon the furnace action by Johnson's hearth heat theorem. We now know that the factors limiting the burden have their head, center, and focus in the hearth. If we would know what these factors are, we must look at the heat relations of the hearth.

The hearth heat relations center around the fact that it is necessary to maintain a temperature of about 1,500 deg. C. (2,732 deg. F.), at least this is the approximate temperature of the combustion zone as measured by the temperature of the slag running from the furnace at a level somewhat below that of the tuyeres.² It appears then that a sine qua non of satisfactory furnace operation is maintenance of the minimum temperature of 1,500 deg. C. in the tuyere zone where the metal and slag receive their final heat treatment before sinking into the crucible. In ac-

*Paper read before the American Iron and Steel Institute, New York, May 20, 1927.

†Metallurgical Engineer, Washington, D. C.

cordance with the Johnson theorem and with the well-known exactions of furnace operation, it may safely be assumed that it is the primary function of the air combustion to maintain this temperature, that is, to supply heat available at 1,500 deg. C. at a rate at least equal to the rate at which this high degree heat is absorbed by the work done and by the various cooling actions going on in this particular zone of the furnace. When this heat supply is ample the furnace is said to be "hot" and everybody is happy.

If it were possible to draw up an accurate heat balance showing the items of heat absorption to which the heat available at 1,500 deg. C. is appropriated and distributed, we would then have a detailed accounting of the furnace action in the form of a proven theory to which variation of action could be referred for explanation and adjustment. From our present data on the specific heat capacities of carbon, air and the combustion gases we can at least approximate the truth as to the amount of heat made available at 1,500 deg. C. in the oxidation of carbon by air of a given blast temperature and moisture content. Per pound of carbon the amount of heat so available is the heat of CO formation, plus the blast heat, less the heat of blast moisture decomposition, and less the difference between the sensible heat carried at 1,500 deg. C. in 2.33 lbs. of CO with 4.26 lbs. nitrogen and the heat of 1 lb. of carbon at the same temperature. With blast temperature 1,200 deg. F. (649 deg. C.) and five grains moisture per cu. ft., the available heat is 1,110 lb.-cal. per lb. of carbon burning CO with 5.6 lbs. air, estimated as follows:

CO formation from 1 lb. carbon.....	2,430 cal.
5.6 lbs. air, 649 deg. C. $\times$ 0.25 specific heat.	907 cal.
	3,337 cal.
Less: Decomposition 0.055 lb. H ₂ O $\times$ 3,225.....	177 cal.
	3,160 cal.
6.6 lbs. CO and N ₂ 1,500° C. $\times$ 0.2727..	2,700
1 lb. carbon 1,500 deg. C. $\times$ 0.4333..	650
	2,050 cal.
	1,110 cal.

We thus are able to measure with some exactness the total heat of oxidation available for the maintenance of the hearth temperature. In so doing, we have also, of course, measured the resistance which is overcome in maintaining this temperature. Some day undoubtedly the details of this heat dissipation will be learned with sufficient certainty to dispel the last doubt as to what makes the furnace so much of a gas producer. By that time it will probably have become a better iron smelter.

For the present, knowing the total heat absorbed in keeping the hearth hot and the manner of its generation, it is possible to draw a general conclusion as to the gas producing function of the furnace. This conclusion seems not only to be warranted by the facts, but to be well nigh inescapable: in order to supply the high temperature heat required in the hearth it is necessary to burn with air a certain amount of carbon relative to the iron; the gas thereby produced carries upward from the hearth amounts of sensible heat and reducing power, both of which are greatly in excess and out of all proportion with the respective amounts of heating work and reduction required to be done above the hearth; a result of the excess heat being the reversion of a substantial amount of CO₂ to 2CO by reaction with the coke, reflected in "solution" loss.

Quantitatively, there is in best practice a production from hematite ore of 1.5 lbs. basic pig per lb. of coke carbon; this production involving, with ratios of 45 per cent slag and 40 per cent stone, some 692 calories of heating work per lb. pig or 1,038 calories per lb. coke carbon as charged, in addition to 1,640 calories for reduction of iron (94 per cent) and 70 calories for reduction of 1 per cent silicon, making 2,565 calories of reducing work per lb. carbon. The total smelting work, 3,603 calories, accounts for 40 per cent of the 9,007 calories total energy of a pound of carbon burning with 5.6 lbs. of air at 1,200 deg. F. The top gas composition with a volume ratio of 38 per cent CO₂ to 62 per cent CO shows that 39 per cent of the total coke (and air) energy is undeveloped and unutilized in the furnace. The relation of the 50.5 per cent coke carbon equivalent of the ore oxygen with the limestone CO₂ to the 38 per cent CO₂ ratio in the top gas shows that 12.5 per cent of the coke carbon is gasified to CO otherwise than by air and that another 12.5 per cent of the coke carbon reverts from CO₂ to CO (or remains as CO). Hence, of the 62 per cent of the coke carbon in the top gas as CO, 25 per cent, involving some 40 per cent of the 39 per cent energy loss, is attributable to the solution loss reaction, CO₂ + C = 2CO, absorbing 38,880 calories, 3,240 calories per lb. of carbon gasified. The solution loss of 12.5 per cent and the 6.5 per cent of the coke carbon in pig and flue dust leave 81 per cent of the coke to burn with air and generate high temperature heat in the hearth. With a 1,200 deg. F. blast and five grains moisture the heat available at 1,500 deg. C. is 899 calories (0.81 $\times$ 1,110) per lb. of coke carbon charged and the heat carried up from the hearth in the gas is 1,660 calories over the 526 calories absorbed by the carbon on its way to the hearth. With 600 calories chargeable to radiation and water-cooling in the furnace as a whole, it is thus seen that the total heat generated by the air (899 + 1,660 or 2,559 calories per lb. of carbon charged) is in excess by 921 calories of the heat absorbed in the smelting work proper (1,038 calories) and radiation (600 calories); this surplus heat being exactly balanced by 405 calories absorbed in solution loss (0.125 $\times$ 3,240) and the 516 calories of top heat including moisture evaporation. The surplus heat as generated by the air is some 87 per cent of the heating work, besides a negligible balance of heat generated in reduction. The hearth heat, being about a third of the total heat, is over half of the heat absorbed in smelting work and radiation. If it could be assumed that half of the total smelting work and radiation devolved upon the tuyere zone where the temperature approximates 1,500 deg. C., it would follow that the heat carried in the gas from the hearth is more than double the smelting work and radiation taken care of above the hearth

$$\frac{1660}{1638 - 899}$$

Since of course such an assumption is not warranted, the fallacy involved therein need not be discussed here. For the present the facts themselves are of sufficient interest: in a furnace consuming 500 short tons of coke daily or 850,000 lbs. of carbon, 81 per cent being burned with air, 478 lbs. of carbon per minute, 1,500 deg. C. heat is generated in the oxidation of carbon and dissipated in some way at the rate of 530,580 lb.-cal. per minute (16,800 kw.) which is 899

calories per lb. of coke carbon charged and 600 calories per lb. of pig iron produced. In addition, the combustion products, CO and N₂, carry away from the hearth as sensible heat 989,900 calories per minute (31,000 kw.), 1,660 calories per lb. carbon, 1,106 calories per lb. pig. The latent energy of the CO formed in the hearth is 2,710,260 calories per minute (86,000 kw.), 4,592 calories per lb. carbon, 3,062 calories per lb. pig. The stupendous heat generation by the air oxygen, equivalent to 64,000 hp. of energy, with a 23 per cent loss in water-cooling and radiation is going on at a rate 87 per cent faster than the rate of absorption in useful smelting work; 15 per cent of the total heat being dissipated (becoming latent) in gasifying carbon and 19 per cent going to top heat. At the same time the CO gas formed from the air oxygen is flowing upward at such a rate that the iron ore going down in countercurrent can (under the laws of chemical combination) oxidize only 55 per cent of this CO to CO₂, with the result that 45 per cent of the air CO, together with the equivalent of another 30 per cent of this gas formed in the solution of coke, leaves the furnace with its latent energy unutilized therein. The gas flow from the top has a calorific power in CO alone of 64,500 kw. and 2,680 kw. in blast hydrogen. The smelting work uses 65,400 kw. The power equivalent of the entering oxygen is 136,500 kw., of which 13,700 kw. is contributed by the blast heat and 2,680 kw. become latent in decomposition of blast moisture. The 1,500 deg. C. available heat, 16,800 kw., is some 12 per cent of the total.

Such are the facts. They would appear almost to interpret themselves in terms of reasons why such an immense plethora of energy is involved in performing the functions of the smelting process and consequently why the furnace is so much of a gas producer. Clearly, the limited amount of available hearth heat limits the burden to that which can use about 55 per cent of the total energy associated with the air blown, less radiation. Equally clearly the surplus heat actually generated by the air is a factor, if not the chief cause, determining the rate and extent of gasification of carbon by CO₂. This gasification involves not only loss or absorption of heat above the hearth, but also failure of a substantial proportion (12.5 per cent) of the coke carbon to burn with air and supply hearth heat; this failure being in effect a substantial loss (15 per cent) of hearth heat. This gasification of carbon is thus responsible for about 40 per cent of the total CO loss, the other 60 per cent being due to the surplus CO formed by the air and not used in reduction (45 per cent); the total CO loss being the equivalent of 75 per cent of the air CO, representing 47 per cent of the total air energy. Clearly then, the gas producing function of the furnace, in which iron ore and limestone serve as "endothermics," is intimately associated with the surplus energy necessitated by the hearth conditions. Gruener's ideal is not more nearly attained because the demand for heat in the hearth is so great that, in supplying it, the shaft is literally flooded by a surplus (87 per cent) of heat; with a result, in the nature of countercurrents, that an eighth part of the coke, more or less, instead of developing heat actually absorbs it, free heat becoming latent. And, it may be added, there must always be solution loss, unused CO and a hot top so long as the burden is limited by a resistance involved in hearth temperature main-

tenance to that which can use only a fraction of the total heat developed while overcoming that resistance, whatever it may be. In short, the furnace suffers from too much heat superinduced by too little.

Consideration of the heat relations in the furnace as a whole leads inevitably to a conception of solution loss as being a direct effect of surplus heat. This conception differs from the quite generally held view of the carbon gasified otherwise than by air as a source of heat. It would seem to be evident that the only carbon associated with a positive heat development is that burning with air, the carbon otherwise gasified being involved in heat absorption, whether it be in the misnamed "direct" reduction or by reaction with CO₂. The principle involved is seen in the fact that when oxygen burns a pound of carbon to CO₂ it develops 8,100 calories and when the same amount of oxygen burns 2 lbs. of carbon to CO it develops 4,860 calories—double the carbon giving 40 per cent less heat; the second pound of carbon absorbing 3,240 calories in reaction with CO₂; with a fixed amount of oxygen, the more carbon, the less heat. The same oxygen burning CO to CO₂ develops 11,340 calories. The point about solution loss that needs to be emphasized is that, whatever its mechanism, it involves either a failure to develop heat or an absorption of heat otherwise developed, and whether heat becomes latent or remains latent would seem to be immaterial. The loss, absorption or failure is measured by the endothermic effect of the gasification of carbon by CO₂ plus the heat of CO formation which would be developed if the carbon could burn with air. In the case of CO₂ from limestone, it is obvious that the carbon gasified absorbs heat and there is no detectable distinction between such CO₂ and that formed in the reduction of oxides by CO. In any case it would seem to be misleading to regard the carbon gasified as a source of heat. The only known way to get heat out of the solution loss reaction is to reverse it! $2\text{CO} = \text{C} + \text{CO}_2$ develops 3,240 calories per lb. of carbon deposited, which in burning with air oxygen develops 3,160 calories more. This reaction takes place in the furnace as is well known, but not to an extent sufficient to offset the greater reverse effect. Surplus heat, under the principle of energy conservation, prevents. Development without use is impossible.

II. The Disposition of Hearth Heat

How a man in the iron smelting business finds himself willy-nilly in the power business has been described. The fact that in putting enough heat into the hearth a great deal too much is applied above the hearth gives a rational basis upon which to proceed in seeking ultimate causes for the marked gas producing effect, an often-noted symptom now explored and measured. Our diagnosis is as yet only partial. We have localized the trouble. We know that we have to deal with a well defined case of plethora due without doubt to hearth trouble. But the trouble has not been defined. The hearth must be examined further.

The first thing to be observed about the hearth heat is its relative size. In a furnace making per pound of coke carbon 1.5 lbs. of basic iron from hematite with 45 per cent slag and 40 per cent stone, burning 81 per cent of its coke with air at 1,200 deg. F. and five grains moisture per cu. ft., the hearth heat (available at 1,500 deg. C.) is seen to be some

12 per cent of the total energy as measured by the air blown. It is about 21 per cent of the total energy used in the smelting work including reduction, with the radiation and water-cooling added. The hearth heat is some 35 per cent of the total heat primarily generated by the air in CO formation. It is 54 per cent of the amount of heat absorbed in melting and heating the metal and slag, burning the stone and taking care of radiation and water-cooling; reduction by CO absorbing no heat. The hearth heat is 1,110 lb.-cal. per lb. of carbon burning with air, 899 calories per lb. of coke carbon charged, 600 calories per lb. of pig produced. To afford a basis for comparison of rather diverse practices Table A gives the hearth heats of seven different furnaces in terms of the relationships just stated.³ In the next to last line of the table the term "Primary Efficiency" designates the proportion of the total heat generated by air oxygen which is absorbed in smelting work and radiation; the remainder being the heat accounted for in solution and top heat. The last line gives the CO required for reduction in terms of percentage of the CO formed by the air.

latent in sulphur removal, the reaction expressed as $\text{FeS} + \text{CaO} + \text{C} = \text{CaS} + \text{Fe} + \text{CO}$ being only slightly endothermic (seven calories for 2 per cent S in 50 per cent slag). The formation of slag from CaO , SiO_2 , Al_2O_3 , etc., evolves heat as does solution of carbon in iron. The one item clearly using some of the 1,500 deg. C. heat is the unavoidable loss by water-cooling and radiation. The only basis for belief that any great part of the high temperature heat is devoted to the smelting work proper would seem to be the relatively great speed at which American furnaces are driven. Against this belief is the fact that in the Lowthian Bell furnace (No. 2) shown in Table A, which was worked at about one-seventh the modern American rate, the hearth heat requirement was apparently not smaller, the greater slag ratio complicating the comparison. The charcoal furnace in the table (No. 6) made 20 tons daily with a 36-in. hearth and 1,200 cu. ft. working volume. It does not appear that increased speed of driving, in general, is accompanied by poorer fuel economy. Finally, cold blast charcoal practice in which after charging off a reasonable loss in tuyere water and radiation very lit-

TABLE A—COMPARISON OF BLAST FURNACE PRACTICES

	1	2	3	4	5	6	7
	Southern furnace	Lowthian Bell	High sulphur coke	Illinois, 13% scrap	Mathesius	Austrian charcoal	Experi- mental
Coke burned with air, per cent.....	81.2	87.5	80.9	81.4	80.9	85.7	93.3
Hearth heat, per lb. coke C. cal.....	794	817	809	780	932	433*	782
Hearth heat, per lb. pig. cal.....	749	833	642	509	625	230	906
Ratio slag to pig, per cent.....	80	152	62	43	47	60	60
Hearth heat to total energy, per cent.....	11	10	11	11	13	6	9
Hearth heat to total work, per cent.....	24	21	21	19	22	8.6	23
Hearth heat to primary heat, per cent.....	32	31	32	32	36	19	29
Hearth heat to heating work, per cent.....	49	41	51	51	56	27	43
Specific efficiency, per cent.....	30.5	36.4	37.3	38.7	39.4	53.5	26.9
Primary efficiency, per cent.....	65	76	64	64	65	73	67
Air CO used in reduction, per cent.....	35	38	50	52	55	70	29

*It is to be noted that in the charcoal furnace the heat available at 1,400 deg. C. is 30 per cent greater than that at 1,500 deg. C., the difference being about 150 calories per lb. carbon burning with air.

It is perhaps natural, upon finding in the coke furnace that the amount of work done in the hearth is equal to a large part of the heat absorbing work done in the whole furnace, to jump to the conclusion that this hearth work is made up of work inherent in the smelting process. At any rate this assumption seems to have been quite generally made.⁴ Before accepting such an assumption, however, at least before basing upon it any important conclusions, it will perhaps be well to examine it. An assumption appears valid only provided that: (1) it has a reasonable basis in fact; (2) known facts are not inconsistent with it; (3) it explains what it is used to explain; and (4) no other valid explanation is available. The assumption that heat-absorbing smelting work equal to about half of the total of such work done in the furnace devolves upon the hearth and absorbs heat available at 1,500 deg. C. would seem to be unable to meet any of these requirements.

1—As a matter of fact none of the smelting work requires a minimum temperature of 1,500 deg. C. Limestone is completely dissociated at much lower temperatures, reduction of iron oxides to metal requires only a moderate temperature, iron and slag both melt at temperatures considerably below 1,500 deg. C. and even reduction of silicon takes place below 1,500 deg. C. Very little heat appears to become

the high temperature heat is left available, tends to show that very little of the smelting work devolves upon the hearth.

2—The idea that the smelting process inherently requires anything like half of its heat absorbing work to be done at 1,500 deg. C. would seem to be effectually negated by charcoal practice in general. Furnace No. 6 gives perhaps an extreme example but none the less a typical one. Here it is seen that the hearth work per pound of pig (230 calories) with a 60 per cent slag ratio is little more than a third of that in No. 5 (625 calories) with 47 per cent slag. The heat available at 1,500 deg. C. (with a small blast heat) is only 19 per cent of the heat generated by the air as compared with 36 per cent in No. 5 with a blast heat above the average. The 1,500 deg. C. heat is only 27 per cent of the total heat absorbing work, while in the American coke furnaces it runs from 49 to 56 per cent. The fact that a charcoal furnace requires only about a quarter of its effective heat to be available at high temperatures is inconsistent with an assumption that one-half of the effective heat in coke furnaces is absorbed in smelting work done at high temperatures. The fact indicates that resistance to the higher temperatures which distinguish coke from charcoal practice is due to something other than the smelting work proper.

3—The assumption fails to explain either the hearth or the shaft action. If it is to be assumed that all the heat found to be available at 1,500 deg. C. is absorbed in items of smelting work, it becomes necessary to estimate these items. This involves so many purely arbitrary assumptions that one might well shrink from the task. It is however easy to show the faultiness of these item assumptions as made by others and thus their failure to account for the hearth heat. For example Johnson,⁵ having to account for 611 calories (1,100 Btu.) as the hearth heat per pound pig, after noting that this figure was 70 calories (100 to 150 Btu.) too low (p. 69), figured that reduction of 1.5 per cent Si took 100 calories (180 Btu.); that the slag absorption of heat "not imparted in shaft" was 83 calories (150 Btu.); that the iron similarly absorbed 67 calories (120 Btu.); and that there was lost in cooling-water, radiation and "conductance through bottom" 189 calories (340 Btu.); a total of 439 calories (790 Btu.). Having yet 172 calories (310 Btu.) unaccounted for, he simply wrote this amount down to reduction of 10 per cent of the ore and thus balanced the account. The manifest errors are as follows: the reduction of silica with gasification of solid carbon absorbs 4,900 calories per lb. Si without considering the difference in sensible heat at 1,500 deg. C. between the reagents and the products which would reduce this figure somewhat, hence 1.5 per cent Si can absorb at the most 74 calories of the available heat per pound pig as supplied by the air oxygen; similarly the constant used for reduction of iron, 1,650 calories (2,970 Btu.) per pound pig, is the heat of formation of Fe_2O_3 without allowing any credit for CO formation which would, considering the likelihood that any unreduced iron coming to the hearth is in the form of FeO, make the constant not more than 650 calories per lb. Fe and the heat absorbed in 10 per cent of the iron reduction not over 61 calories. Leaving aside the consideration that there is no evidence that any appreciable part of the iron reduction takes place in the hearth, the above assumptions on their face leave unaccounted for 207 calories per lb. pig or nearly one-third of the hearth heat. The figures used by the Oxygen Committee⁴ are arrived at in the same general way. It perhaps need not be pointed out that at least a part of the iron and slag are already melted above the hearth, nor need it be said that it is questionable whether any "conductance through the bottom" is properly chargeable against the heat available at the hearth temperature. The water-cooling in the combustion zone is measurable, but the radiation loss can only be guessed at. Some credit also should be allowed for the positive heat of slag formation and that of carbon solution in the iron. In view of the foregoing, together with the much lower hearth heats in charcoal practice, it would seem to be safe to conclude that the hearth heat is not to be accounted for in smelting work. The assumption does not explain the hearth action. Moreover, if it is assumed that about a third of the total heat, which is available in the hearth, does one-half of the total work, it is thereby assumed that the other two-thirds of the heat, which is applied above the hearth, is only half used. This would seem to require more explanation than is afforded by a mere assumption that only half the work is done above the hearth. If this assumption were true, however, increasing the height of the shaft should save the hearth some work through doing more above the hearth. Experience shows that increasing

height results in little, if any, improvement. The assumption does not explain the shaft action.

It is, of course, not to be doubted that the smelting work exerts a cooling action in the hearth, but an assumption that this smelting action accounts for any great part of the total resistance to temperature maintenance is clearly unjustifiable. It is entirely possible that only a small fraction of the smelting work develops upon the hearth.

4—Nor is the smelting work assumption justifiable on grounds of lack of other explanation for the facts. The present writer some time ago offered an hypothesis in explanation of the necessity for limiting the burden as in fact it is limited.⁶ This explanation would seem to complete the necessity of discarding or at least of drastically revising, the assumption which has apparently been relied upon to account for the relatively great hearth heat dissipation in coke practice. This hypothesis may be stated broadly to be that nitrogen fixation in the combustion of air and carbon constitutes a serious heat absorbing factor resisting temperature maintenance in the hearth by limiting the proportion of oxidation heat made available at the hearth temperature; in short, that nitrogen fixation primarily limits the available heat and thereby the burden.

Subjecting the nitrogen fixation hypothesis to the same tests applied to the smelting work assumption, it will be seen that the hypothesis is broadly based upon the fact that with each pound of free oxygen 3.3 lbs. of nitrogen pass through the tuyeres and upon the fact that, under the conditions existing in the combustion zone, nitrogen, instead of being, as usually assumed, inert, is reactive, its reactions absorbing heat. In coke furnaces the slag is relatively basic, a condition in itself conducive to the formation of carbo-nitrogen compounds, besides tending to drive alkalis out of combination with silica and alumina to form cyanide vapor. Alkalis are always present in ores and coke ash and naturally tend to accumulate by successive vaporization and condensation. Cyanides are always present in the hotter zones of the furnace. The gas formed at the tuyere noses, where oxygen is still free, contains a substantial excess of nitrogen over the air ratio, changing within a few inches to a substantial deficit of nitrogen (excess of CO)⁷ indicating successive oxidation of nitrogen compounds, freeing nitrogen, followed by fixation of nitrogen where reducing conditions prevail. Above the combustion zone the gases resume almost their normal air ratio, showing but little reduction of metal in the combustion zone and substantial reversion of cyanide or other nitrogen compounds above the combustion zone. Measurements have shown actual concentrations of cyanide vapor in the combustion gases corresponding to those indicated by the quantitative gas changes, namely the equivalent of a fixation of about 4 per cent of the air nitrogen. This would absorb upwards of 30 per cent of the hearth heat as developed in oxidation. The clouds of "smoke" or fume seen when gases blow from the hearth, averaging more than half cyanide with much slag, are confirmatory.

The smaller hearth heat requirements in charcoal practice are consistent with the nitrogen hypothesis. Charcoal slags are notably siliceous, as permitted by the low sulphur, this low basicity tending to restrict nitrogen fixation and to retain alkalis in the slag and thus lessen their accumulation in the furnace with

successive formation and reversion of cyanide vapor. The higher temperatures maintained in coke furnaces, together with the limier slags, would seem to set up their own resistance, both by way of increased nitrogen fixation and also by way of slag vaporization. Sometimes furnaces using ores of higher alkali content and having much sulphur to contend with, and therefore requiring a heavily basic slag, have been known to increase their coke consumption from 2,100 lbs. to 2,800 lbs. in changing from basic to foundry iron. Another fact of practice consistent with the nitrogen hypothesis is the sensitiveness of the hearth to variations in stock distribution. The less the heat actually available in the hearth to take care of the smelting work unperformed above the hearth, the more sensitive the hearth will be to variation of this work. A substantial heat absorption by the air nitrogen leaves less of the heat from the oxygen available for useful work and would thus account for hearth sensitiveness. In general, the marked lack of uniformity in furnace action is at least partially explainable on the basis of variation in the extent of nitrogen fixation due to variations in temperature, basicity, alkali accumulation and the like. Sticking in the shaft is consistent with increased vaporization followed by condensation. Furnaces work better when acid; and acidity restricts nitrogen fixation.

Finally, the nitrogen hypothesis affords a simple, but comprehensive explanation of the outstanding fact which has long stood in need of explanation, the fact that the burden is limited to that which uses not more than 40 per cent of the coke energy, with the accompanying, related fact that 40 per cent, more or less, of the coke energy is not developed, 20 per cent, more or less, being associated with losses comprising carbon in pig and flue dust, radiation and top heat. It will be seen in Table A that the four American coke furnaces all show practically the same primary efficiency, 64 to 65 per cent, that is, the same surplus of heat in terms of percentage of the total heat generated by oxygen, namely 35 per cent. With the surplus heat generation there is also a surplus of reducing power which may be expressed in the same terms as 45 to 65 per cent of the total. In other words, 35 per cent of the coke burning with air produces surplus heat which is reflected in solution loss and top heat; 45 to 65 per cent of the reducing power being also surplus. Fixation of 4 per cent of the air nitrogen has been seen to account for about 30 per cent of the heat of oxidation available at 1,500 deg. C., and it may therefore be said that 30 per cent of the coke burning with air is necessitated by the nitrogen fixation. Hence in the best practice, nitrogen fixation furnishes a reason for 30 of the 35 per cent surplus heat and for 30 of the 45 per cent surplus reducing power; solution loss, due to surplus heat, being responsible for some 40 per cent of the total CO loss in addition to the surplus CO formed from air oxygen.

Nitrogen fixation affords a possible explanation of the diminishing return from higher blast heats which seems to be unexplainable by the smelting work assumption. If a definite proportion of the smelting work requires a temperature of 1,500 deg. C., then it may be expected that increase of available heat, which accompanies rise of blast temperature, would permit a proportionate increase of burden. This is far from what usually happens, as illustrated by furnace No. 5, having 20 per cent more available hearth

heat than No. 4, but carrying only 2 per cent more burden, as shown by the respective efficiencies. The diminished return becomes intelligible as a result of increased nitrogen fixation and vaporization actuated by the increased heat and absorbing the greater part of it. In this connection the increased "smokiness" of unduly hot furnaces appears significant. The frequent failure of the furnace to "take its heat" is also intelligible as being connected with vaporization and condensation, causing pressure rise as usually observed.

Perhaps not the least impressive feature of the nitrogen theory is its serviceability toward explaining certain facts that appear otherwise unexplainable. As yet there has been established no fact incompatible with it, while the theory itself has a sound basis in fact. It seems at least to possess the distinction of being the one theory offering to account systematically for low smelting efficiency. If it fails, then we are at present without a valid explanation of the furnace action.

Biography

¹R. Franchot, "Specific Efficiency of the Blast Furnace," A. I. M. E. paper No. 1596 C, October, 1926; Mining and Metallurgy, September, 1926.

²Johnson, "Principles, etc., of the Blast Furnace," page 74; Royster, Joseph and Kinney, "Significance of the Hearth," Blast Furnace and Steel Plant, March, 1924, page 154.

³R. Franchot, "Specific Efficiency of the Blast Furnace," A. I. M. E. paper No. 1596 C, October, 1926; Mining and Metallurgy, September, 1926.

⁴See for example the Report of Advisory Committee on "The Use of Oxygen or Oxygenated Air in Metallurgical and Allied Processes," Bureau of Mines Reports of Investigations No. 2502, July, 1923, page 10.

⁵Principles, etc., page 72.

⁶R. Franchot, "Economic Significance of Cyanid Accumulation in the Blast Furnace," A. I. M. E. paper No. 1490 C, February, 1926; Blast Furnace and Steel Plant, 14 (1926, May and June) pages 217, 254; "The Fixation of Nitrogen as Cyanid," Ind. and Eng. Chem. 1924, p. 235.

⁷Perrot and Kinney, "Combustion of Coke in Blast Furnace Hearth," Trans. A. I. M. E. 69 (1923) p. 543.

Blast-Furnace Irregularities

In the course of a paper read recently before a joint meeting of the Staffordshire Iron and Steel Institute and the Birmingham Metallurgical Society at Dudley, Mr. R. S. Bethell pointed out that a blast furnace in operation was subject to many forms of irregularity, due to a variety of causes. Such irregularities required immediate detection and prompt measures taken for their rectification, otherwise a train of evils might follow. Probably the most common form of irregularity was the entrance of water into the furnace, either by way of leaky tuyere, cooler or cooling plate, leakage from the tuyeres being more frequent than from any of the cooling devices. Leakage might be due to burning or abrasion of the cooling device. There were several ways in which the leakage of water into a furnace might be detected. Very frequently a good furnace charger would give intimation that the gas at the furnace top was very "wild," and on the slag being flushed off, the appearance of the slag also indicated that water was entering the furnace from some point. The slag became dark in color, showed a black crust, or appeared foamy or glassy. A look round the tuyeres would frequently reveal the cause of trouble, as the water might be seen rising up in a jet form in front of the tuyere. Sometimes the leakage was not so easily detected.

The Continuous Rolling of Sheet Steel*

Principle of Continuous Rolling as Applicable to Rolling Sheets
as to Rolling Wire Rod, Billets, Etc.—Economic Factors
Involved in a Successful Application

MECHANICAL engineers are such large users of sheet steel that any material developments in the art of making it become of interest to them, particularly when these developments are of a really significant character. This is the situation at present in steel-sheet rolling. The art, which has undergone comparatively little modification in the last 50 years, is now passing through a development which is nothing less than revolutionary. Not only the mechanical methods of making sheet, but the entire economic structure of this vast industry is being pounded to pieces and reshaped in a new manner, which will probably leave it ultimately entirely different from what it was only two or three years ago. The password to the secret of these striking changes is "continuous rolling."

Continuous Rolling First Used on Wire Rod

The principle of continuous rolling is a very old one. Wire rod was probably the first product which was so rolled, its length being so great and its size so small that it would have been impossible to roll wire rod in return mills without reheating between passes, and such reheating, even if practicable, would increase the cost of the material inordinately. Because of this, from the earliest days in wire-rod rolling the glowing, snakelike rod as it came out of one pass was picked up and returned through another in such a manner that the rod might have been considered as going through several passes at the same time.

The early arrangements for doing this were, of course, very crude—a man, often a boy, with a pair of tongs catching the rod as it came from one pass, and running up to the next roll and inserting it in another pass. In addition the work was extremely dangerous, as a man could easily miss catching with his tongs the writhing rod, which might then coil about him or pierce his body. Accidents of a very terrible nature were quite frequent, and with the equipment then used were unavoidable. The possibilities of continuous rolling as applied to wire rod were, however, so obviously promising that earnest endeavors were made to improve the machinery. Bedson, Garrett, and finally Morgan developed the continuous rolling of wire rod to a point where enormous outputs per mill were obtained with a high degree of safety for those engaged in the work, and at an economy that could not be excelled by any other method of rod production.

The Morgan continuous mill may be considered as representative of that type. It consists of a series of horizontal roll stands arranged one after the other, so that the piece to be rolled enters the first stand and travels in a straight line through the mill to the last stand, where it issues as a finished article, thus making but one pass through each stand of rolls. Of course, as the pieces being rolled in several different stands at the same time are elongated through

corresponding reduction of area, it is necessary that the surface speeds of the different sets of rolls be so proportioned that each set will travel at a speed as much greater than the preceding one as the lengthening of the piece requires. This is done essentially by a system of driving gears. To care for the wearing down of the rolls they are made adjustable (in billet and rod mills, usually the bottom roll only), and as a further precaution against small irregularities that cannot be overcome by adjustment, each set of rolls is purposely set to run at a slightly greater speed than that required to conform to the speed of the preceding set, so as to keep the rod under tension at all times.

The success of the continuous wire-rod mill led to the application of the same principle to several other types of mills, such as billet mills, sheet-bar mills, and even blooming mills, until finally the conviction grew among rolling mill engineers that any product could be rolled in a continuous mill provided economic considerations permitted it, the only reservation being made by operating men being the rolling of sheet. Of this more will be said later.

Advantages of Continuous Rolling Process

The matter of economic background for continuous rolling is an important one. The chief advantages of this type of mill are high output and low labor costs. Among the chief disadvantages is the great number of rolls, which not only makes the first cost of the mill very high but adds immensely to the cost of rolls for different sections. For the same reason much time is required for roll changes. Hence the mill is best adapted to roll large amounts of one section continuously, and not at all to the rolling of a very large number of sections, each in comparatively small tonnages.

As stated above, whenever a claim was made that continuous rolling could be applied to any material that the economics of the case warranted, it was made with a reservation excluding sheets. There was a reason for this. Quite a number of years ago a bold attempt to roll sheets continuously was made at one of the plants of the American Sheet & Tin Plate Company, a subsidiary of the United States Steel Corporation. The attempt proved to be a dismal failure. Complete particulars of what happened have never been released for publication, but from such information as could be collected it would appear that mechanically the mill was successful to the extent that it did roll sheet in a satisfactory manner. Commercially, however, it was decidedly a failure. Just why this was so is not quite clear and it may have been partly on account of the cost of rolling; more likely, however, it was because this type of mill was built ahead of its time. Continuous mills can be profitable only when a steady and substantial tonnage can be fed into the rolls day in and day out without much changing. A continuous mill is substantially a heavy-tonnage producer, and will pay only if used as such.

*Mechanical Engineering.

Before the war there was no such tonnage for sheets, and orders ran usually only in lots of a few carloads. It was only the vast development of stamping, metal furniture and automobile manufacture, etc., that gave the big orders on which sheet mills could be run for weeks at a time. At any rate, the American Sheet & Tin Plate Company's continuous sheet mill was not a success, and its failure created a feeling in the trade that the type was not worth while experimenting with. Moreover, since the cost of a continuous sheet mill may run up to anywhere from \$5,000,000 to \$7,000,000, it will be easily understood why few companies could get up enough enthusiasm to attack the problem again. Nevertheless there was a steady progress in applying the principle of continuous rolling, and, for example, strip and hoops, which are nothing but narrow sheets, have been rolled continuously for a number of years. The question arises, therefore, why, if sheet 8 in. wide (called hoop) could be rolled continuously, was there such a to-do over the matter of rolling wider material?

This was due to the fact that there are certain things which can be done with short rolls that cannot be done so well with long rolls, and the difference between the rolling of narrow strip and wide sheet lying at the very foundation of the present revolutionary developments is of sufficient importance to warrant devoting a few words to it here in explanation.

Problems Involved in Sheet Rolling

To a layman a steel roll 12 in. in diameter has the appearance of being an enormously rigid structure. Actually, however, when it is subjected to the great forces involved in the rolling of steel and also to the high temperatures encountered therein, the roll undergoes a certain amount of bending distortion which very rapidly increases with the distance between the roll bearings. Furthermore, the power required to roll steel increases roughly with the cubic content of reduction, which, in this case, would mean with the width of the sheet. The size of the bearings naturally increases with the amount of power which has to be handled by the roll, and there must be an obvious relation between the diameter of the roll and the size of the bearing, the former increasing with the latter.

It would appear from the above that if an attempt were made merely to increase the size of a strip mill so as to roll wide sheets, the following situation would be encountered. To take care of the wider sheet a bigger roll would have to be used. The bigger roll would require heavier bearings and greater power. The greater power and heavier bearings would produce a greater tendency toward heating at the bearings. The heat from the bearings would flow into the rolls and expand diametrically the parts nearest the bearings, with the result that instead of a properly flat sheet, one that grew progressively thinner toward the edges would be produced, and because of the great width of the roll there would be also an additional bending tendency which would increase this crowning effect. Furthermore, the ordinary means used to avoid such an occurrence in other forms of rolling, such as giving the rolls an initially convex shape or heating the middle part of the roll with a torch, would be inapplicable, because of the thin gage of the material rolled. These and other considerations have proved to be sufficient to bring about a realization of the fact that a strip mill cannot be converted

into a continuous sheet mill by merely increasing the size of the rolls and spreading the bearings apart, and yet conditions in ordinary sheet rolling are such as to make the prospects of continuous rolling extremely attractive from many points of view.

The ordinary sheet mill is probably one of the largest employers of labor in the entire industry, and what is more, the labor used in the sheet mill is of a highly skilled, high-priced kind, with an organization unusually well able to enforce its demands. In non-continuous mills sheets are rolled from sheet bars, which are bars from 8 to 12 in. wide and from $1\frac{1}{4}$ to $\frac{7}{8}$ in. thick, the length of the bar being usually the width of the sheet to be rolled. The ordinary sheet mill is divided into two divisions, the hot mill and the cold mill. The hot mill consists essentially of one or two stands of rolls, furnaces, and a shear. Two stands of rolls are generally used, one stand being known as the roughing or sand mill and the other as the finishing or hot mill. Both stands are of the two-high non-reversing type.

Procedure Followed in Rolling Sheets

The roughing mill is also called the soft mill, because the rolls carry no hardening chill, and is also sometimes referred to as a breakdown mill, a jump mill, or a balanced mill, the last two, however, designating also the type of construction of the roughing mill. Just to indicate the amount of work done in a non-continuous mill, the following is quoted from "The Making, Shaping, and Treating of Steel," by J. M. Camp and C. B. Francis, fourth ed., p. 945:

Breaking Down the Bars. The helper deposits the two bars upon the fore plate of the roughing mill, where any loose scale or dirt is removed by a few strokes with a steel brush. With the mill screws adjusted to effect the proper draft, the rougher then immediately grasps one of the bars with his tongs and passes it through the mill, to be grasped with tongs by the catcher on the opposite side of the mill. Then while the catcher is elevating the bar, using the billy for leverage to return it over the top roll, the rougher feeds the second bar into the mill and grasps the first, which the catcher is now steady on the top roll for the second pass. As the screws are quickly adjusted, this pass is made at once. These movements are made in rapid succession until the bars have been roughed down to the gage that can be taken by the finishing mill. From this point the manner of completing the roughing is adapted to the gage of the sheets. On the finishing mill, the pairs are handled in the same way as they were on the roughing mill for a number of passes until the single pieces are about $\frac{3}{32}$ in. thick. The two roughed-down bars are then matched, that is, placed one upon the other, and rolled for the last two or three roughing passes. After roughing down, these sheets must be parted, a result that is accomplished by grasping one corner of the top sheet with tongs and pulling upward while the bottom sheet is held down with the foot. As a rule, the roughing down is continued until the bars have been elongated to one-half the length of the sheet desired, or to a gage that gives a weight per square foot twice or four times that of the finished sheets. Sheets heavier than 16 gage are generally finished at once without reheating, but all sheets of lighter gage must be reheated to complete the rolling.

Next comes hot rolling proper. Sheets 13 gage and heavier are rolled singly or one at a time, while sheets lighter than 13 gage are finished in packs of two or more. This is called "doubling," and for a long time was done by hand. The roller turned that end of the sheet which he held in his tongs over the other end and laying his foot on the folded sheet to prevent its springing back, grasped the two ends at once with his tongs and thrust the fold into a doubling machine. This consisted of a pair of flat surfaces whose action was that of a pair of shears with very blunt edges falling flat on instead of passing by each other. The doubled sheet was then reheated and rolled out as if it were a single sheet. The sheets thinner than doubles were produced by folding this doubled sheet a second time, four thicknesses being passed through the rolls at once. Then again when sheets reached a certain size they were simply laid one over the other and rolled as in the case of a single sheet, this being known as packing or matching. Of late in the United States mechanical doublers have been developed and found extensive application. Nevertheless it is easy to realize what a tremendous consumption of labor all these operations involve, especially when due consideration is taken of the fact that each sheet which requires so much work in the way of handling, represents only very small tonnage by way of weight.

The whole process of sheet manufacture was contrary to the American principle of employing as much machinery as possible and as little labor as possible per ton of goods. Mechanical manipulators had everywhere taken the place of hand labor, except in the sheet business. The result was that, compared with other departments of the great steel industry, the output of steel mills was low, the labor consumption high, and the cost of production correspondingly elevated. The answer to the problem of devising an effective method of continuous rolling lay primarily in just two things, the four-high mill and roller bearings. The idea of the four-high mill goes back to the Lauth mill. B. C. Lauth, of Pittsburgh realizing that a smaller roll would do the work more rapidly than a larger one if it only had sufficient strength to withstand the pressure, devised a mill in which a roll of small diameter was supported throughout its length by one of larger diameter. The small center roll in the Lauth mill is generally about two-thirds the diameter of the top and bottom rolls, which serve alternately to support it against the bending stresses set up in it by the plate being rolled, and as the strength of the body of the two rolls of similar length subjected to transverse load varies directly as the cube of their respective diameters, the strength of each large roll is about $3\frac{3}{8}$ times that of the supported small roll. The Lauth idea has been since applied in several different ways. Edouard Mathey, a Swiss, is said to carry the idea of using small rolls to the utmost limit. To prevent the springing or bending of the very small working rolls used, which are of hardened steel, he supports them by four much larger rolls whereby the pressure is spread over eight bearings of large diameter, and as the rubbing speed of these is low and the pressure per unit of surface likewise low, the power used is reduced. The Bliss cluster mill is another development of the Lauth idea, and here likewise instead of one supporting roll, several are used.

The four-high mill goes a step further, however,

than Lauth did, and provides a supporting roll not for one but both of the working rolls. In this way rolls of strip-rolling sizes may be made strong enough to roll wide sheets without having the power transmitted to the working rolls inordinately increased. The question of heating of bearings to which so much attention had been devoted before was solved very simply by the development of roller bearings of sufficient capacity.

The First Continuous Sheet Mill

When it became clear, as it did theoretically, that both the economic conditions and the state of development of the art were such that the building of a continuous mill was possible, all that was necessary was for some one to find the courage and the money to do it. The Columbia Steel Company, Elyria, Ohio, was an old company which had recently fallen into the hands of men with a pioneering spirit, engineering ability, and suitable financial connections. They had already put through a development as to the possibility of which there was a good deal of skepticism, namely, the continuous annealing of strip. A little over a year ago they took over the Forged Steel Wheel Company, of Butler, Pa., which up to that time had been a losing proposition financially, secured the necessary capital, and built the first continuous sheet mill in existence. Even before this mill was completed their example was followed by several other companies, possibly five, and one or two under very serious consideration. The continuous sheet mill has definitely come to stay, and from all indications there is no longer any serious doubt as to its being a success both technically and commercially. If any doubt now exists it is concerned with the future of non-continuous mills, but that is a matter which will be briefly discussed later.

From what has been said above it will be noticed that while the Columbia Steel Company was the first to build a successful continuous sheet mill (except, of course, the American Sheet & Tin Plate Company mill which was dismantled), no new principle is here involved. Because of this, there are no basic patents on continuous sheet mills, and as far as patent protection is concerned, each mill is limited to its ability to cover certain features of operation such as layout, mill drives, shears, etc. There is therefore very great reluctance on the parts of the mills to give out any more information than they can help regarding their installations. This very natural feeling will be thoroughly respected here, and no detail of operation will be described which might in any way be considered as revealing confidential matters; further, the mills described will be designated by letters and not by names.

General Features of Present Continuous-Sheet-Mill Practice

The general features of present practice—which is exclusively American, as no continuous mills have been built abroad—are already sufficiently clear to be stated here. In the first place, a continuous sheet mill can be operated economically only in connection with a steel plant, which means that the ordinary sheet mill working from sheet bar only cannot be converted into a continuous sheet mill without many millions of dollars of additional investment. The second significant feature is that the continuous sheet mill is an outgrowth not of the present sheet mill, but

of the present strip mill, and as a matter of fact, it is strip-mill and not sheet-mill labor that is usually taken over to run the new mills. The continuous sheet mill cannot use the ordinary thin and narrow sheet bar simply because there is not enough metal in it to produce a long sheet.

The following practice of mill K may give a general idea of the present layout. The start is made in a 27-in. two-high reversing breakdown mill. As a raw material for the start, slabs from 3 to 5 in. thick, of suitable width and a maximum length of 12 ft., are used. In this roughing mill the slab is reduced to a thickness of $\frac{3}{8}$ in. and from this it goes to the hot mill, which consists of five stands of four-high mills, and is reduced there to about 16 gage. It should be clearly understood in this connection that the four-high mill to be used for continuous sheet rolling is very different from the ordinary three-high Lauth mill, particularly in that it must be so arranged as to permit a very fine up-and-down adjustment between the rolls. From the hot mill the sheet goes to the cold mill, which consists likewise of a series of four-high stands. There is here a difference in practice, mill K using the universal-mill breakdown end so as to deliver to the hot mill an article of specified width. Mill L, on the other hand, relies on the use of vertical rolls in the first set of continuous rolls to achieve the same effect.

No official figures of production of continuous mills have been given out, and the following data are quoted from statements made by persons not connected with the companies, but considered to be reliable. It is stated that at Butler, Pa., 225 tons of sheet 17½ in. wide were rolled in an 8-hr. shift, and that on wider sheets an output as high as 1 ton per min. has been attained. This means that continuous sheet mill can very nearly do in a day what an ordinary mill would be glad to do in a week. There has been an effort to apply the principle of continuous rolling to part of the mill operation so as to obtain some of its benefits without going the full way of the big investment which the new process requires. A mill in the Pittsburgh district specializing in high-grade alloy sheets has therefore hit upon the following scheme. It has now hot mills and will continue to use them, rolling the material down to 11 gage. It proposes to put in four stands of four-high mills of the type used in continuous rolling and expects to reduce the gage from 11 to 24. The interesting feature about this mill is, however, that very long sheets are neither required nor desirable for the purpose for which the particular product rolled by that mill is intended. The maximum length of the sheets is therefore only about 15 ft. and the stands are to be spaced 20 ft. apart, so that the sheet in rolling will pass directly from stand to stand, but will at no time go through two stands at the same time. We are therefore dealing here with consecutive rather than continuous rolling—in mills, however, designed for continuous rolling.

Savings Possible by Application of Continuous Principle to Sheet Rolling

No reliable statements are available as to the saving in cost made by the application of the continuous principle to sheet rolling, but it is stated that this saving may be as high as \$15 per ton, which, assuming that everything works out all right, does not seem to be impossible. If we assume further that continuous mills can regularly maintain their production within

the high figures mentioned above, it would appear that some seven continuous mills could take care of all the sheet rolled today in the United States. Of course, the continuous mill cannot handle small ton-nages or odd sizes, and that much will be always left to the present non-continuous mill. And the non-continuous mills, or at least some of them, are already looking for a means of salvation by rearranging their plants so as to start with a slab, break it down to about 11 gage in a jobbing mill, and finish in a few stands of continuous mill, which will materially cut down the cost of production, eliminate some of the most expensive forms of labor, and hence bring them within competing distance, at least on the smaller lines, of the full continuous mills. Nevertheless the future of the ordinary non-continuous sheet mill is by no means auspicious.

Present and Future Prospects of Sheet-Steel Industry

As regards the present economic background of the sheet business, certain features are in favor of and certain against the continuous sheet mill, with the balance probably on the favorable side. The demand for sheets has been steadily increasing, and such moves on the part of the industry as the formation of the American Sheet Trade Extension Committee, are certainly helpful in this direction. The advancement in knowledge of sheet stamping, pressing, etc., is also increasing the range of users of sheet. The new varnishes and lacquers which make sheet-steel articles more durable are expected to be a contributing factor in the same direction, and yet with the demand for sheet steel decidedly on the increase, the profits of mill operators have been low and show no tendency upward. This is ascribed by every one concerned to the intense competition for business among the operators and the very keen ability on the part of the buyers, particularly the larger companies, in turning this competitive condition to their benefit. The state of the industry being thus, there is every reason to believe that the lower prices which the continuous sheet mills are already quoting and at which they can make better profits (assuming that everything works out all right) than the non-continuous mills at their higher prices, will attract the business their way. The tendency toward the so-called hand-to-mouth buying is cited as against the interests of the continuous sheet mills in that it is apt to break up business into parcels which may eventually prove too small for them to handle. So far, however, there does not seem to be any indication of this as seriously affecting the business of the only existing mill of that kind, and there is every reason to believe that with the price attraction, purchasers will be willing to give sufficiently large orders to get the full benefit of the lower quotations. The continuous sheet mills will roll every width between strip and approximately 42 in. and every gage, and are therefore capable of taking care of any market requirements. There is very little doubt, therefore, as to the permanency of this new development. In the United States continuous sheet rolling has come to stay. There is every indication that it will remain essentially an American development. Considering the profound changes which it has created in a great industry and the further fact that no new inventions are really involved in it, it is rather surprising that no continuous sheet mills have been built before. They have, however, come to stay.

OFFICIAL PROGRAM

Twenty-third Annual Convention

—AND—

Iron and Steel Exposition**Syria Mosque
Pittsburgh, Pa.****June 13th to 18th
—1927—**

All Sessions will be held at Pittsburgh Athletic Association Annex which is the Old University Club.

MONDAY, JUNE 13TH

9:00 A. M.

Registration

9:30 A. M.

Business Session

S. S. Wales, Chairman

10:00 A. M.

"Electrical Heating in the Iron and Steel Industry." By AI&SEE Electrical Heat Committee, Geo. H. Schaeffer, Chairman.

11:30 A. M.

"Electrical Developments in the Iron and Steel Industry." By AI&SEE Electrical Development Committee, W. H. Burr, Chairman.

12:30 P. M.

Informal Reception and Luncheon for Members and Guests of AI&SEE. To take place at Annex of Pittsburgh Athletic Association.

1:30 P. M.

C. L. Baker, Chairman

Session of Safety Engineering Division of AI&SEE.

"Safe Practices in Connection With the Operation of High Tension Power," by A. N. Cartwright, General Supt. Power Division, West Penn Power Company, Pittsburgh, Pa.; Geo. E. Gramm, Electrical Engineer, H. C. Frick Coke Company, Scottdale, Pa., and Thomas E. Hughes, General Foreman, Carnegie Steel Company, Duquesne, Pa.

2:30 P. M.

Discussion by Safety Division and Electrical Engineers and Superintendents of Iron and Steel Plants, Central Stations and Mines.

7:30 P. M.

Official Opening of Iron and Steel Exposition.

9:00 P. M.

W. E. Miller, Chairman

Informal Reception and Dance for Members and Guests. Annex of Pittsburgh Athletic Association.

TUESDAY, JUNE 14TH

B. R. Shover, Chairman

10:00 A. M.

Symposium: "Anti-Friction Bearings for Heavy Duty Steel Mill Applications With Particular Reference to Roll Necks," by F. W. Cramer, Asst. Elec. Supt., Bethlehem Steel Company, Johnstown, Pa.; C. J. Klein, Engineering Dept., United Engineering & Foundry Company, Pittsburgh, Pa.; F. H. Buhlman, Engineering Dept., Rollway Bearing Company, Syracuse, N. Y.; E. C. Gainsborg, Engineering Dept., SKF Industries, Inc., New York, and Fred Waldorf, Engi-

neer, The Timken Roller Bearing Company, Canton, Ohio.

11:45 A. M.

"The Application of Synchronous Motors in Steel Mills," by Harry A. Winne, Industrial Engineering Dept., General Electric Company, Schenectady, New York.

WEDNESDAY, JUNE 15TH

W. J. Harper, Chairman

10:00 A. M.

Combustion Engineers' Day

Auspices Combustion Engineering Division AI&SEE "Recent Boiler Plant Installation at Edgar Thomson Works, Carnegie Steel Company, Braddock, Pa." by R. D. Abbiss, Special Engineer, Carnegie Steel Company, Braddock, Pa.

11:30 A. M.

"The Flat Suspended Open Hearth Roof," by A. L. Foell, Chief Engineer, Donner Steel Company, Buffalo, N. Y.

7:00 P. M.

A. G. Place, Chairman

Annual Dinner Dance for Members and Guests of AI&SEE at Ball Room, Schenley Hotel.

THURSDAY, JUNE 16TH

10:00 A. M.

"Electrical Installations at New Structural Mills, Homestead Steel Works, Carnegie Steel Company, Munhall, Pa.," by C. A. Menk, Electrical Superintendent, Carnegie Steel Company, Munhall, Pa.

THURSDAY AFTERNOON

Inspection Trip to New Structural Mills of Homestead Steel Works of Carnegie Steel Company, Munhall, Pa. Make your reservation by card.

FRIDAY, JUNE 17TH

A. J. Standing, Chairman

10:00 A. M.

"Fifteen Years of Steel Mill Illumination—What Change?" by Ward Harrison, Director, Illuminating Engineering Division, National Lamp Works of General Electric Company, Cleveland, Ohio.

FRIDAY AFTERNOON

Golf Tournament. Details may be had from Bulletin Board at Syria Mosque.

SATURDAY, JUNE 18TH

Maintenance Employees' Day at Iron and Steel Exposition from 10:00 A. M. to 10:00 P. M.

Oxygen in Steel and Non-Hardenability

Oxygen Probably Present as an Iron, Carbon, Oxygen Alloy—Ternary Alloy Indicates Non-Hardenability—
Effects of Carbon and Alloys Discussed

By JOHN D. GAT*

THE industrial importance of the possibility of differentiating between easily and difficultly hardenable steels has brought about a considerable amount of investigative work, with the result that the close study of the properties of non-hardening steel has given eventually a better understanding of the underlying phenomena of non-hardenability. Some investigations point out that one has to distinguish between modifications in crystalline structure induced by crystallization or grain growth from those properties caused by and attributed exclusively to the peculiarities in composition which can be associated with the non-hardening properties only.

Viewed from this standpoint, the shape, size, relative dimensions of grains, character of the gradation zone or character of the core of a carburized sample cease to be indicators of the hardening properties of a given steel. It is not difficult to prepare, or rather to collect, two series of specimens embracing an identical and a very wide range of grain sizes and shapes of crystalline units, one series the members of which will possess perfect hardenability while all members of the second after carburization and quenching will show a difference in hardness between 20 and 30 points Rockwell C. Moreover each member of the unhardenable series will have an unmistakable index of their non-hardenability. On carburized steels suitably etched with acid reagents this index is a white lining in which is imbedded the cementite mesh of the hypereutectoid zone. On annealed steels, or in the core of carburized specimens, this structural feature will show itself, after etching with reagents of sodium picrate type, as brown inclusions, roughly corresponding to the grain outlines, but easily distinguishable from cementite by the lack of peculiar sharpness of the outlines and the frequent digressing from thin straight lines characteristic of cementite and by a tendency to assume a pattern somewhat resembling the appearance of proeutectoid ferrite. The true nature of this structure is not as yet established, but much evidence points to its being an alloy of iron, carbon and oxygen and to its having a most important bearing on the carburizing properties of steel. If it is not present the steel will harden without any trouble, on the other hand traces of this substance as observed under a microscope will result in a difference in hardness on quenching in tap water, in the limits mentioned in the preceding paragraph.

The presence of oxygen in these inclusions is indicated by circumstantial evidence only, therefore, in order to throw some light on the true role played by this gas in inducing a steel to become unhardenable a series of experiments was conducted in which oxygen was introduced in the metal intentionally.

The difficulty of incorporating in the steel the correct amounts of oxygen had to be overcome. Instead of taking an oxygen free steel and introducing in it

gradually increasing amounts of the gas, it was decided to select a steel with a very high oxygen content, one slightly above one-tenth of 1 per cent oxygen, and to add to it increasing amounts of a deoxidizer, in this case aluminum, until all known tests failed to show even traces of the gas.

Necessarily all other variables had to be kept constant and this was accomplished by the use of a high frequency induction furnace of the Ajax Northrup type. The value of this apparatus for an investigation of this kind can hardly be over-estimated. A stock of highly oxygenated metal was provided sufficient for about two dozen heats. It was melted in this furnace, under a cover, in 40-lb. lots and the molten metal was freed from a part of its oxygen by the addition of predetermined amounts of aluminum. The steel so produced was carburized as usual, and after solidification was examined under a microscope and checked for hardenability. The percentage of oxygen in it was determined by the vacuum fusion method.

Though this procedure possesses several shortcomings, as for example contact with atmospheric oxygen, loss of a part of the deoxidizer in the slag, lack of a close control of the temperature (deoxidizer was added as soon as the charge was melted thoroughly), failure to make an accurate analysis of the residual aluminum, etc., it still presented a true picture of the transformation of the metal from an unhardenable one into one entirely satisfactory. This change came abruptly and was simultaneous with the disappearance of the last traces of the iron-carbon-oxygen alloy as shown by microscopical examination.

This, if not proves, at least strongly supports the point of view that "free" oxygen has very much to do with the resistance to hardening. This term "free" oxygen is understood here as oxygen not tied up in the stable oxides of aluminum, silicon, etc., but that held in solution by the iron.

Experiments in Open Hearth

Having established the basic facts connected with the production of unhardenable by laboratory experiments one is tempted to verify them in actual furnace practice. The step from a 40-lb. Ajax Northrup high-frequency induction furnace to 100 tons open hearth is not as long as it appears to be at first glance. The experimental procedure followed was practically identical. Instead of taking specimens from small heats, one can depend on a large open hearth as a source of supply of samples which constantly, but not gradually, are changing in their properties. They give, when taken at intervals sufficiently frequent, a rough picture of the behavior of the bath, which is a function of numberless factors existing in practically every metallurgical apparatus.

Expressing the effect of the complexity of factors present in an open hearth as their integral, it is

*Metallurgical engineer.

not difficult to see, that during the short time interval between two consecutive samplings the change occurring will be of the same order as a differential of a function. The integration of them will give a true picture of the conditions encountered during the whole process, but taken separately, they may be considered to be constant. Introduction of some major change in the system, as for example, an addition of an alloying substance, will, therefore, produce an effect which may be considered without great inaccuracy, as peculiar to this substance, provided, of course, that the time interval requirements are fulfilled.

In the establishment of a permissible time minimum, normal working of a furnace was considered as the only one actually depending on the totality of the factors other than the addition of alloys. This embraces the time from the moment when the bath melted, more accurately, when the lime was up, to the time of the first addition marking the beginning of working the heat, i. e., a period when the building of the slag was going hand in hand with the decarburization of the metallic charge and the burning off of its components.

Slag composition was selected for the purpose of checking because physico-chemical changes are reflected by it more pronouncedly, and are easier to observe than transformations taking place in the metallic portion of the bath. Slag composition could be produced during this period as straight line curves obtained by plotting percentages of a given oxide against time, this method being preferable to the use of polyaxial diagrams representing the whole system. During this stage of the heat the changes introduced after a lapse of 5 minutes were small enough to warrant the use of this interval in planning the sampling.

Determination of the necessary time maximum was connected with the study of a comparatively large number of heats, which, in order to simplify the subject, belonged to the same type, i. e., carbon chrome, and were followed by a still larger number of those in which the behavior of metal was approached from the hardenability point of view. A point of considerable interest is the possibility of presenting the phenomena occurring during all these heats by one of them selected at random, because the general trend of the reactions was practically identical in all disregarding intentional wide variations in the character of the charge, order, quantity and kind of alloys used, and the temperature conditions prevailing during melting, working and tapping.

Charged used:

Hot basic iron	74000 lbs.
Heavy skulls and molds	26000 lbs.
Bar mill crops	47000 lbs.
Foreign scrap	33600 lbs.
Pressed sheets	20500 lbs.
Flashings	22500 lbs.
Total metallic charge	223500 lbs.
Limestone	28500

The lime was up at 7:10 A. M., the charge completely melted at 7:35 with the analysis usually aimed to with the type of heat (C 0.70, Mn 0.30, S 0.023, P 0.023, Cr 0.10, Ni 0.20). The type of charge given above is so widely different from that generally used in the plant where the experiments were conducted that some explanation is necessary. The heat was made for experimental purposes with the aim of find-

ing the relation between the quality of scrap, amount of oxidation and the resulting properties of steel. With this point in view instead of adhering to the usual charge of blooming mill crops and a large proportion of heavy melting scrap, the charge was made as bulky and oxidizable as the standards of the plant would permit without passing to the realm of open sheet bar stock. Furthermore, oxidation was increased by addition of ore, in absolute disregard of the standard practice, 2,000 lbs. 55 minutes after melting and 1,000 lbs. 1 hour and 15 minutes after the first portion.

This brought the carbon down to 0.20 per cent at 10:55 A. M., and the working of the heat began by addition of 1,000 lbs. of spiegel,* at 10:10 followed by 1,200 lbs. of silicon pig† at 10:30, 3,300 lbs. of ferro chrome‡ at 11:01 increased by 200 lbs. 36 minutes later and 2,000 lbs. of silico manganese at 11:19 A. M. The heat was tapped on the hot side and the slag was in good shape. Ladle additions consisted of 850 lbs. of 50 per cent ferro-silicon, 175 lbs. of ferro-carbon-titanium and 45 lbs. of aluminum.

The heat described above does not represent either usual or good practice as such is considered in the plant of the corporation with which the writer is associated, but it has the intrinsic value of being representative of the conditions which are met in an open hearth. It is true that with the change of practice directed towards the prevention of oxidation in the melting down and in the elimination of the highest possible amount of dissolved oxygen from the bath by proper regulation of slag and composition and temperature, numerical values expressing different stages of this heat will be replaced by different figures, but even with the best conditions practically available the stages of the making of any heat will be connected with the same characteristics in regard to the oxygen content and to the hardening properties depending on oxygen content.

No attempts were made to illuminate the conditions accompanying the making of this heat from the scientific point of view. Physico-chemical phenomena present here are far too complicated to be treated in a short paper, and a few analyses of slag composition, no matter how complete and frequent, or graphs of the oxidation rate of different elements in the charge will obscure rather than clear the understanding of the processes. It was thought that experimental evidence gathered under laboratory conditions, where close control was possible might clear the way to a correct understanding of the influence of oxygen on the hardenability of steel while operations on a production scale, viewed from the same standpoint, might show whether or not the same laws can be extended from practically ideal experimental conditions to an exceedingly complicated system existing in an open hearth.

Appearance of the Bath

An interesting way of presenting the subject is in recording the appearance of the bath at its different stages by a series of photographs of specimens taken from it at predetermined intervals, and properly carburized. Saturation with carbon brings out clearly the presence of oxygen in the form of the alloy referred to at the beginning of this paper and permits

*3 per cent C, 20 per cent Mn.

†2 per cent C, 15 per cent Si.

‡5.75 per cent C, 62.86 per cent Cr.

a direct visualization of the behavior of this gas in the metal. The amount and distribution of the white areas of cementite surrounded with the alloy in question give an idea of the percentage of the latter which could be expected in a given sample, while the disappearance of the last traces of it indicates the point in the making of steel when the metal becomes suitable for hardening purposes.

The first sample withdrawn from the bath showed that the steel still contained a considerable amount of carbon, (0.70 per cent). It was strongly oxidized in melting down, so that Fig. 1 shows a distinct cementite lining though the areas of white segregation are neither abundant nor large. Three hours later, when the carbon was reduced to 0.27 per cent, the percentage of oxygen rose considerably, (Fig. 2). In this sample every line of cementite is imbedded in the white eutectoid alloy and the latter is present also in large masses. At this stage saturation with gas reached its highest point since an addition of ore had by this time become powerless in changing markedly the character of the steel. (See Fig. 3). Fig. 4 shows the appearance of the steel after addition of the second lot of ore. Manganese effects de-oxidation of iron slowly and incompletely. A sample

taken as soon as the manganese worked through still shows a decidedly oxidized metal; even 20 minutes after its introduction in the bath there is no difficulty in distinguishing in certain areas unmistakable traces of the iron-carbon-oxygen alloy, though most of cementite net-work is freed of it. (See Fig. 5). Silicon acts rapidly and strongly. Five minutes after its addition all of the oxygen alloy was gone and the cementite could crystallize out freely on carburization, (Fig. 6). Ferro-chrome, as a rule containing much dissolved oxygen particularly if it was made by the reduction of elements other than carbon, was not able to oxidize the bath again, though it did change somewhat its crystallographic appearance, (Fig. 7). Introduction of silico-manganese was powerless to bring any changes in already thoroughly deoxidized metal, and additions to the ladle resulted only in reducing the crystalline dimensions of the steel, (Fig. 8).

A point deserving special attention is the independence of the degree of oxidation from the carbon content of steel. In case of carburization this was repeatedly proven by the simultaneous presence of carbon and oxygen as shown in cementite divorce, but one is not warranted to extend the conclusions reached

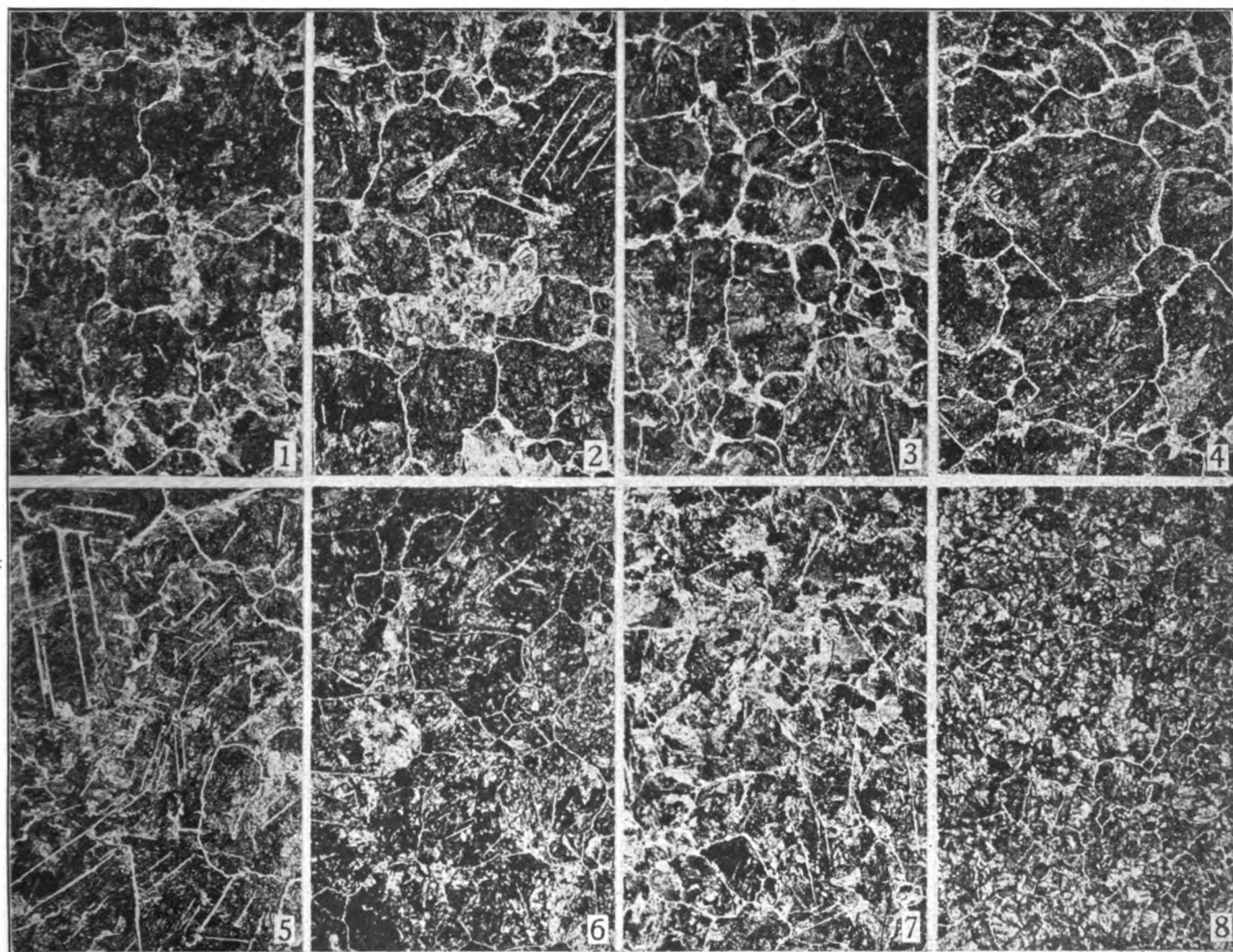


FIG. 1—When the liquid pool first forms. FIG. 2—When melted C 0.27 per cent, Mn 0.22 per cent, Si 0.005 per cent. FIG. 3—40 min. after addition of 2,000 lb. ore. FIG. 4—10 min. after second addition of 1,000 lb. ore. FIG. 5—20 min. after 1,000 lbs. spiegel worked through. FIG. 6—5 min. after silicon pig addition, C 0.26 per cent, Mn 0.20 per cent, Si 0.004 per cent. FIG. 7—20 min. after chrome addition, C 0.25 per cent, Mn 0.22 per cent, Si 0.004 per cent. FIG. 8—Ladle test C 0.35 per cent, Mn 0.74 per cent, Si 0.24 per cent.

in experimentation at comparatively low temperatures and in a decidedly reducing atmosphere to considerably higher temperatures, different condition of the substance, and to oxidizing conditions. The equilibria of the iron-carbon-iron oxide system at low temperatures thoroughly illuminated by the work of many investigators has not been studied with the same completeness in the range approaching the melting points of steels. In the present paper one has to limit the subject to the mere presentation of available visual evidence refraining from comments that might have a bearing on the prevailing conditions of the gaseous phase, on the temperatures, and on the composition of the bath and the slag.

It can be only stated that a definite equilibrium exists at these temperatures because addition of molten cast iron to a highly oxidized bath is accompanied with a violent reaction, but it terminates long before all available carbon and oxygen are removed as carbon monoxide. The results of an analytical and microscopic study of specimens containing as much as 0.70 per cent carbon, taken after the addition of the molten iron and when the bath was completely melted, strongly support this point of view. One can see here from Fig. 1, that a sufficient amount of oxygen is still present to form a large percentage of the ternary alloy, an observation in absolute agreement with the results of chemical analysis.

If no equilibrium exists, one can expect that there are two opposite sets of reactions, one caused by the deoxidizing effect of carbon, the other striving to introduce oxygen in the metal by the action of furnace gases acting through the slag, and at some time there is a point at which some of the carbon content of the cast iron is used in the reduction of the iron oxide but the oxidizing action of the slag is prevented by the presence of the residual carbon. At this point it should be possible to procure a specimen which after carburization will not show any of the ternary alloy. Very many samples taken from open hearths from the moment when the first pool of liquid metal formed till the addition of the deoxidizers, and not one showed a complete reduction of the oxides.

Chrome-Vanadium Steel

To check this observation some samples were taken from an electric furnace melting a chrome vanadium heat on a white slag. In this process the conditions under which melting takes place are opposite to those in open hearth practice since all efforts are directed towards the prevention of oxidation. With proper care the resulting slag is, if not entirely white, only very slightly colored. This indicates that in the later stages of melting there is no action of oxygen on the metal and the strong reducing conditions existing in the furnace are sufficient to return back to the metallic bath all oxides, with the exception of silica, formed during the first stages of the melting. When the scrap is melting down it is impossible to prevent a certain amount of oxidation, though in this case it is small. The pool of molten metal soon formed at the bottom acts as a nucleus of further reducing reactions. Its composition is not limited by iron and carbon only since there was not enough oxidation to remove all the alloying elements. The small quantity of oxygen carried by the scrap running down comes here in contact with the substances more easily oxidizable than iron with subsequent slagging of the oxides formed. As the metal in the pool is cold, most

of the oxides are reduced by elements other than carbon, a reaction supported by placing under the scrap a small amount of ferro silicon.

When this heat was melted it had a practically white slag and the metal analyzed:

Carbon	.28	per cent
Manganese	.47	per cent
Silicon	.14	per cent
Sulphur	.028	per cent
Phosphorus	.023	per cent
Chromium	.91	per cent
Vanadium	.12	per cent

The sample lay perfectly dead in the test mold and after carburization produced a structure with cementite net work entirely free from eutectoid envelopes of the ternary alloy. Here the influence of 14 points of silicon entirely overbalanced the presence of 70 points of carbon of the open hearth heat as far as freedom from oxygen was concerned.

In an open hearth the scrap carrying usually only small amounts of silicon, may be comparatively free from oxygen, but absorbs a considerable amount of this element when running down. At the beginning, even the small amount of silicon present is able to reduce a part of oxides formed so that the metal remains free from the iron-oxygen-carbon alloy until its content is reduced to a percentage at which an equilibrium between it and oxygen dissolved in iron is reached. Any further oxygen absorbed by the bath is held in it irrespective of carbon content within the limits present in steel, but can be reduced by addition of a large excess of carbon, as happens when molten pig is poured in the furnace, or by the addition of silicon, aluminum and other deoxidizers. At this state the metal contains around 0.04-0.06 per cent oxygen, remaining practically unchanged until the carbon is reduced very low, to about 0.01-0.02 per cent, when the percentage of oxygen may raise up to 1/10 of 1 per cent.

Silicon

The presence of silicon does not by itself guarantee the freedom of steel from dissolved oxygen. Coming in contact with oxidized metal silicon burns rapidly until an equilibrium between three constituents of the system Fe-FeO-Si is established. Further increase of gas content has a comparatively weak influence on the amount of silicon still contained in the bath. Referring to the analysis of the samples of the heat discussed from time to time, the scrap began to melt until the bath was tapped; one can see that the equilibrium was reached at about 0.005 per cent silicon in the iron-carbon-oxygen system (before addition of the alloys) and decreased then to about 0.004 per cent. Addition of a large excess of silicon, converting the steel from an oxygenated steel into one suitable for carburization and hardening, does not need any special explanation as to its action. Silicon was oxidized at the beginning consuming oxygen dissolved in iron and then reducing ferrous oxide in the slag. Further oxidation would undoubtedly restore previously existing equilibrium conditions, but in this case it was prevented by the introduction 31 minutes later of chromium, which is more easily oxidizable than iron. Chromium oxide presumably insoluble in iron was eliminated from the system by upward settling so that no oxygen was left to combine with iron, thereby leaving silicon unprotected and it was

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Oxidizing Reactions in the Blast Furnace*

Free Oxygen in Hearth Gases Results in Re-Oxidation of a Part of the Reduced Iron—Effect on Furnace Capacity— Measures Used to Minimize Re-Oxidation

NEITHER oxidation nor reduction is continuous in the greater number of iron-smelting processes. Secondary reactions take place as a rule; their effect on the quality of the product and on its economical production require the closest attention on the part of the smelter.

In the old Catalan hearth the air had to pass through a thick layer of glowing charcoal before reaching the ore. Alternate layers of small lumps of ore and charcoal covered the mouth of the tuyere. The carbon dioxide formed in front of the tuyere was immediately reduced to monoxide. The ore, surrounded as it was by an exclusively reducing medium, was de-oxidized to a spongy iron which rapidly absorbed carbon. But the small lumps of ore mixed with charcoal and pounded solid placed above the orifice of the tuyere, escaped in greater part from the influence of the blast. The iron merely melted without being reduced, and accumulated in the lower part of the hearth, where it decarburized to spongy iron. By judiciously proportioning the quantity of small ore, the furnace could be made to produce at will mild, fibrous iron or steel, if little or no ore was used or any intermediate quality. The refining action—that is, the oxidation of the carbon—could only be obtained with a liquid ferruginous slag, which acted not on the iron itself, but on the material associated with it. During the whole course of the process the spongy iron was surrounded by an atmosphere of neutral gas, which prevented any re-oxidation. No noxious reaction, no reversal of the process, could take place, and the productive capacity of the furnace per unit of cubic capacity was very high—about double that of the modern blast furnace.

In the finery hearth, which differed but little structurally from the bloomery, the charcoal was used in large lumps, heaped up loosely and not pounded. The broken pig-iron was kept at about 7 in. to 8 in. from the tuyere-plate it was melted under the influence of an oxidizing flame. The molten iron dropped through the hot, loose charcoal lumps, was oxidized and gathered as wrought iron in the lower part of the furnace.

The two processes may be compared as follows:

	Catalan hearth	Finery hearth
Solid phase	Reducing	Reducing
Gas phase	Reducing	Oxidizing
Final result	Reduction	Oxidation

The comparison seems to point to the preponderating influence of the gas phase.

Blast Furnace

In the blast furnace the hearth and the lower part of the bosh are full of more or less large lumps of coke. The iron, reduced in the upper part of the furnace, carburized, and more or less combined with foreign substances, melts at a certain height above

the tuyeres, and finds its way, in the form of drops, through the interstices between the lumps of coke, to the liquid metal accumulated in the hearth. The path of the drops of iron is in all cases sinuous, and their progress down to the level of the tuyeres slow; the same may be said also of the liquid slag which accompanies them. Both drops of iron and of slag come successively within the influence of the solid phase when in contact with the coke and that of the gas phase in front of the tuyeres. The coke may carburize whatever iron has not yet reached the point of saturation in this respect, and should the slag contain (which normally it should not) ferrous-oxide compounds, these will be reduced. The effect of the solid phase consists in the carburization of the raw iron, and eventually in the reduction of the ferrous constituents of the slag.

The effect of the gas phase at the tuyere level depends largely on the density and more or less porous nature of the coke. These are conditions which affect the rapidity with which the carbon dioxide, formed at first by the contact of the incoming air with the hot coke, is reduced to monoxide. The smaller and denser the coke and the higher the temperature, the more rapidly this transformation takes place, and also the dissociation of the watery vapor brought in with the blast.

Thus we have in front of each tuyere a volume of gaseous mixture of free oxygen + CO_2 + H_2O , whereas at the centre of the hearth we have only CO + N . About the extent in both a vertical and a horizontal direction of the oxidizing gas phase we know at present nothing, but we may be certain that it has practically no oxidizing effect on the liquid slag, which, being mainly composed of calcareous clay silicates, can suffer no alteration from the action of oxidizing gases. These latter, on the contrary, have a powerful refining effect on the drops of liquid iron, counteracted to a certain extent by the white-hot coke, but not so much as to prevent the formation of a certain quantity of ferrous oxide, which is absorbed by the slag. The slag in its turn acts on the liquid iron in the same way as the additions of ore in the open-hearth furnace. All the foreign substances in the iron bath tend, according to the prevailing temperature and its degree of concentration, to decompose the ferrous oxide. With the high temperatures in coke furnaces the carbon is the principal active agent, while such low temperatures as prevail in charcoal furnaces are more favorable to the action of the silicon and manganese, and for this reason such furnaces are not suitable for producing iron high in either of these two elements. The blast furnace therefore must partly perform double work. The iron already reduced in the shaft is re-oxidized at the tuyeres, and must again be reduced in the hearth. Furthermore, the chemical energy spent in the shaft for the reduction of the silicon, manganese and phosphorus, is partly lost, as the oxidation of the iron at the tuyeres drives these elements into the slag. It is evident that these reactions must be detrimental to the productive

*Summarized for the "Iron and Coal Trades Review," by H. Savage from an article by Fr. Wust in "Stahl u. Eisen."

capacity of the furnaces. When originally published (in 1910) the author's views on these reactions at the tuyeres were partly rejected and partly ignored. They, however, had already been established in 1895, by certain experiments of Van Vloten. These show that free oxygen exists in the hearth gases, up to a distance of 60 cm. (24 in.) from the tuyere-nozzles, and carbon dioxide is still to be found as far as 90 cm. (36 in.) from the same point, whereas no carbon monoxide is to be found at a less distance than 55 cm. (22 in.); this gas is first found in considerable quantities only when the dioxide has practically disappeared.

More recently (in 1923 and 1925) Perrott and Kinney made for the U. S. Bureau of Mines a number of experiments on large modern blast furnaces (10 furnaces in 1923 and two in 1925), with hearths from 15 to 19 ft. in diameter. The results apparently were, on the whole, similar to those obtained by Van Vloten. Free oxygen was found as far as 60 and 70 cm. (24 and 28 in.), respectively, and carbon dioxide up to 1 m. (40 in.) from the nozzles. The additional fact was also established that variations in the blast-pressure (one atmosphere and $\frac{1}{4}$ atmosphere = 14.70 lbs. and 3.675 lbs. per sq. in.) had little or no influence whatever on the oxygen or the carbon dioxide.

Oxidizing Gas Phase

But the existence of an oxidizing gas phase at the tuyeres of the furnace as disclosed by the U. S. Bureau's experiments can be proved mathematically also. All the carbon meeting the air at the tuyeres is transformed either to carbon dioxide or to carbon monoxide. In neither case is the ratio of the nitrogen to the oxygen affected in the slightest degree. If there are in the air 265 units of volume of oxygen to 1,000 units of nitrogen any loss of oxygen at the tuyeres can only be due to the combination of a portion of it with the liquid iron, provided it was only the carbon that combined with the oxygen. If, on the other hand, the proportion of oxygen to nitrogen is above the atmospheric ratio, it can only be due to a refining action—that is, an exchange between the ferrous oxide of the slag and the carbon in the iron bath.

The exact amount of oxygen taken up by the iron in front of the tuyeres is difficult to determine. Gillhausen found by experiments carried out on four furnaces an average of 3,076 cu. m. of blast, containing 642.9 cu. m. of oxygen at the volume required for the production of one metric ton of pig-iron. Van Vloten, after analyzing a number of samples of hearth gases, found 35 which were low in oxygen by from 1.1 to 23 per cent (the average being 11.77 per cent). Ten other samples showed surplus oxygen, to the extent, in one case, of 58.9 per cent, the average in this case being 18.3 per cent. Taking 642.9 cu. m. of oxygen as the necessary volume for the production of one ton of iron, 11.77 per cent of that quantity = 75.67 cu. m., represents the loss due to the formation of ferrous oxide, that is the oxidation of 378.7 kg. of iron per 1,000 kg. of pig-iron produced. Excesses of oxygen in the hearth gases in front of the tuyeres can only result from the decomposition of the ferrous oxide in the slag. No oxygen combined in the hearth with sulphur, silicon or manganese ever reappears in the gas phase.

From the results of the researches by Perrott and Kinney as to the ratio of oxygen to nitrogen in the

gases in the hearth, Mr. Wust reaches the conclusion that the quantity of iron oxidized at the tuyeres averages about 350 kg. per 1,000 kg. The excess of oxygen towards the centre of the hearth is, however, often very great. Thus Perrott and Kinney found at the centre of the hearth an increase of 106.6 per cent in the oxygen which, according to Mr. Wust's calculations, would correspond to 3,430 kg. of iron. This is of course impossible, but the fundamental error is easily located. The motion of the current of gases over the whole surface of the hearth is by no means uniform; towards the centre there appears to be a more or less motionless layer of gas in which carbon monoxide accumulates. As proved by the experiments the blast does not seem to penetrate more than 1 m. (40 in.) into the hearth, and rises at the edge of the furnace. Finally there is the possibility that the drops of iron passing before the tuyere nozzles are driven by the blast towards the centre of the hearth, where they are taken up by the slag, making it richer in ferrous oxide which in turn explains the high content of carbon monoxide in the gases. This was found by Perrott and Kinney to be as much as 70 per cent CO at the center of the hearth, when theoretically there should have been no more than 34.7 per cent of monoxide. It follows that the increased percentage of oxygen in the gases at the center of the hearth cannot be taken as the basis for calculating the quantity of the oxidized iron, and further, that the formerly accepted hypothesis of an equally effective combustion over the whole surface of the hearth is not consistent with the facts.

The reoxidization of the iron in front of the tuyeres is thus of a wholly unexpected importance, and it seems probable that in the earlier cold-blast furnaces its effect must have been sufficient to annul completely the reducing work done in the shaft and bosh. The surprising results attained by the use of hot blast and more recently of dried air are, in point of fact, due to a diminution in the oxidation zone in front of the tuyeres.

It is a well-known fact that the reduction of ferrous oxide by carbon is a direct reduction, that is an endothermic process absorbing 830 calories per kg. of iron. Heat is therefore consumed below the tuyere level, and it might be urged that the molten iron might be so much cooled down as to solidify and block up the whole hearth. But on consideration it will be found that this cannot occur. The heat due to the oxidation of 1 kg. of iron before the tuyeres is equivalent to that obtained by turning 0.214 kg. of carbon into carbon monoxide, say, $0.214 \times 2,430 = 520$ kg. calories. Thus for each per cent of iron thus oxidized the temperature of the iron bath is raised by

$$\frac{520}{0.2 \times 100} = 26 \text{ deg. C.,}$$

and for 20 per cent minimum of iron, the total rise in temperature would be about 500 deg. C. Some of this heat, be it remembered, is absorbed by the slag. At any rate there can be no question of any solidifying of the bath, except perhaps immediately after tapping, when any liquid iron, which might remain in the hearth, might be so far reduced in carbon by the action of the ferrous oxide in the slag as to solidify and become wrought iron. Some such action is no doubt the cause of "bears" formed at the bottom of the furnace.

In the case of a hearth completely filled with pig-iron conditions differ totally. The temperature may rise to such a point that a portion of the iron may actually volatilize, and be carried upwards with the ascending current of gas in a finely divided form. It is the cause of the pyrophoric properties of the dust deposited near the furnace-throat, and is accompanied by manganese vapors. Water-cooling of the hearth becomes necessary in consequence of the high temperature of the iron in the hearth, in marked contradistinction to what takes place in mixers, which hold masses of liquid iron 10 to 40 times greater, and yet require no water cooling with little or no danger of a piercing of the refractory lining, although this of less thickness than in the case of the blast furnace.

Measures Used to Control

From what precedes, there can be no escaping from the conclusion that, in the usual blast-furnace practice, a considerable hitherto unsuspected portion of the iron already reduced, is re-oxidized to an extent which must seriously prejudice the economy of the process. To minimize such re-oxidation it becomes necessary to restrict, as far as possible, the extent of the oxidizing zone in front of the tuyeres. This may be effected in various ways, as for instance by the use of hot and dry blast, or of oxygenated air, or by increasing the temperature of the blast, but perhaps still more efficiently by enlarging the width of the hearth.

Mr. Wust next compares the extent of the oxidizing zone in three furnaces, with hearths respectively 3 m., 4.5 m., and 6 m. (10 ft., 15 ft., and 20 ft.) in diameter. In the first case the oxidizing zone represents 90 per cent of the surface of the hearth; in the second case 68 per cent, and in the third case 55 per cent only. The wider the hearth the more economical should be the working of the furnace.

From information supplied by different firms who had carried out alterations in their blast furnaces, the author is able to show that an increased horizontal cross section of the hearth had always the effect of increasing the output per unit of capacity of the furnace, the coke consumption being at the same time reduced considerably except in a solitary instance. But even after such an increase in the hearth diameter, the daily output of iron only averaged about 1 ton per cu. m. of hearth capacity in 24 hours—much below that of the bloomery or Catalan hearth, in which the production figure reaches 2.4 tons per day per cu. m. of capacity.

The beneficial effect of wider hearths has often been attributed to another cause, namely, increased volume of blast. This is of advantage in itself, no doubt, but the tables compiled by the author show that the increased output of furnaces which have been altered is always greater in proportion than the increase in the volume of the blast per unit of hearth capacity. Moreover, the lower consumption of coke per ton of iron produced proves that it is not the effect of purely physical causes, which lead to a higher output, but that changed metallurgical conditions, more particularly the restricted oxidation zone in the hearth, also play an important part.

The full advantage of wider hearths, however, can only be realized if the volume of the blast is increased in a greater ratio than the size of the hearth. The influence of the blast, as a matter of fact, is re-

stricted to the oxidizing zone, while in ordinary furnaces occupies about half the section of the hearth. The consequence is that to obtain the best results from an increase in the diameter of the hearth, the furnace must be driven harder than it was before such increase.

Wide hearths, on the other hand, give a much larger cooling surface than narrow ones, just at that part of the furnace, too, where the highest temperature is reached. An increase in diameter from 4 m. to 5 m. (13 to 17 ft.) may give as much as 125 per cent more cooling surface. The water used for cooling also carries off in proportion more heat from the wide hearths than from the narrow hearth. This, again, is a condition which must be met by a harder driving of the furnace if any advantage is to be gained.

Cold-Working

Narrow hearths, as in the past, mean a more restricted surface of contact between the ferruginous slag and the liquid iron. The result is a very slow reduction of the ferrous oxide in the slag, and if any attempt is made to quicken unduly the reaction by forcing the blast, this may lead to cold-working. Now cold-working is not, as is sometimes supposed, the consequence of the ore arriving in the hearth unreduced—an impossible thing after an exposure for hours to a reducing atmosphere at a high atmosphere. Cold-working is due to the fact that enough time has not been allowed, and a sufficiently high temperature has not been reached, to secure the decomposition of the ferrous oxide in the slag. With a wider hearth and a smaller oxidizing zone, less iron is absorbed by the slag, and owing to the larger surface of contact between the liquid iron and the slag, the refining action is much more rapid.

Further improvements can easily be effected in the design and the working of blast furnaces. The effect of the oxidizing zone may be materially reduced by not allowing the descending drops of iron to pass through it, but by restricting their passage to the hearth principally to the central neutral phase. Boshless furnaces would certainly give better results than the usual profiles, and even more might be expected from furnaces of a greater diameter at the hearth than at the throat.

In the downward movement of the burden the coke, by reason of its smaller specific gravity, is driven outwards against the walls of the furnace, while the heavier materials, the ore and limestone, concentrate towards the middle. At the level of the tuyeres only coke will be found, whereas the remainder of the burden melts some 7 or 10 ft. higher up in the furnace, the greater part—if not the whole of it—in the neutral gas zone of the hearth, and is scarcely met by the entering blast or the column of carbon dioxide resulting therefrom. It is to be expected, however, that precisely this current of air would find its way upwards, not through the whole burden, but through the surrounding coke. This question, however, can only be settled by experiment.

It may be recalled in this connection that bloomery hearths of a profile similar to that suggested in this paper have existed for centuries past. In these old hearths the diameter of the hearth was often from two to three times the size of that at the throat. The bloom gradually formed at the bottom of the hearth,

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Discuss Open-Hearth Furnace Problems

Those Interested in the Many Developments in Furnace Construction and Operation Gather at Semi-Annual Technical Session.
Furnace Roof and Walls are Subjects of Particular Interest

By C. W. VEACH*

ABOUT 75 open-hearth superintendents met at the Hotel Statler, Buffalo, N. Y., May 3-5, for the discussion of practical matters pertaining to the basic open-hearth process for making steel. The questions brought up for discussion were all of much interest and elicited a great deal of interest. A summary of the discussion follows.

1—Sloping back walls. It was shown that sloping back walls eliminates hot repairs in this part of the furnace, and prevents silica runs in back side of the bath; saving much bottom repair. Some claim the bulk of the back wall so constructed lasted indefinitely.

2—The new type of roof known as the "suspended" roof came in for considerable discussion. It was the consensus of opinion that this type of roof construction was a radical step forward. But it was also felt that the initial cost would have to be greatly reduced before it would be generally adopted. The suspended roof inspected had made a campaign of 416 heats with few minor repairs, and all, except a small section at each end over the bridgewall, appeared to be good for 100 additional heats. The reason the roof wore out faster at the points mentioned, than it did in the center, where it would naturally be expected to suffer the most, was the bridge walls were abnormally high, and the flame could not be brought down as low as is compatible with a sharp oil flame and safe operation. However more will be known of its merits at the end of another year.

3—The third topic was the method of laying checker brick, and the type of checker brick. This proved a very interesting topic as it is recognized that the efficiency of the open-hearth depends in large part on the regenerator—their ability to store heat and give it up again to preheat the air used for combustion. It seems that very little progress has been made in regard to checkers, either in the quality of the brick or in the method of laying them.

4—The effect of waste heat boilers on furnace operation was shown to be favorable in most cases. Some claim that the boilers improved operating conditions by affording better control—improving the draft and extending the life of the furnace several heats. Where the report was negative it was disclosed that the induction fan was inadequate to the pull after the checkers became clogged. Where the motors were large enough and provided with variable speed control no trouble was encountered. The credit factors ranged from 20 cents to 35 cents per ton of steel made, with an average of about 27 cents per ton of steel.

Brick in Roof

5—Size of brick for open-hearth roof? This question elicited a good deal of interest and brought out the fact that certain parts of a roof wear faster than

other parts. Because his roof wore out more quickly along the skew back one superintendent said he used a brick 16 in. long in a strip extending some 30 or 40 in. from the skew back toward the middle, and stepping down to a 12-in. brick in the remainder or central part of the roof. This thicker roof at the sides he claimed caused his roof to wear out uniformly whereas with a straight 12-in. roof it failed near the skew back while the center was still good for many heats. And as, no doubt, many open-hearth superintendents have had to take a furnace off because the roof had become thin along the skew back, this information may prove of value to them and help them to solve a vexatious problem.

6—Use of silica brick in checker chambers: This discussion disclosed the fact that only a small number of plants have adopted the silica brick for checkers. However it was shown that checkers of silica brick outlasted other kinds, and were highly efficient.

7—The dolomite gun proved an interesting subject, both as a labor and time saver, and for its accuracy in placing the material where it is wanted without scattering it. Users point to the fact that they can eliminate third helpers by using the dolomite gun. This is a big saving in labor cost. By the use of this gun it is possible to make a bottom up in 15 min. and by speeding up it can be done in 10 min. By hand it requires the labor of five to seven men, and takes them 30 to 40 min.—some saving of time we say.

8—The question of size of nozzle and sleeve was brought forward and discussed. It was argued that many factors determine the size of the nozzle—kind of steel, size of heat, number of shutoffs, temperature of steel, per cent of carbon—whether low or high, etc. The size of the sleeve it was said depended partly on the factors mentioned above and on the kind and volume of slag. It was pointed out that the steel foundrymen have long since standardized both nozzles and sleeves.

9—The discussion on the question of furnace yield accounted for losses in the furnace, and the cause of the losses. The furnace losses, as would be expected, were due chiefly to the oxidation of the metalloids where the scrap was not light. When light scrap is used it was contended that excessive oxidation of iron takes place, and iron in a vaporized form is carried out of the furnace with the waste gases. The average yield seemed to be about 88 per cent running from as low as 84 per cent to as high as 92 per cent. This question merits a great deal of study, for if 2 per cent or 3 per cent can be added to the present yield the annual saving will be tremendous.

Pig Iron in Charge

10—What is the low pig iron percentage and the high limit for quality steel? Most of the speakers emphasized the necessity of avoiding the excessive use of ore in making quality steel. It was asserted

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by many the charge should be so balanced in regard to percentage of scrap and pig iron to insure sufficient carbon to work the heat down, using a little ore if necessary, but never having a deficiency of carbon. This question brought out questions bordering on the technical, and it was noticed that influences of some of the elements were thought of by those taking part in the discussion. The silicon desired varied somewhat, some advocating as low as 0.80 per cent, others advocating from 1.10 to 1.30 per cent. Manganese varied in general from 1.50 per cent and lower, to 1.50 and higher, up to 2 per cent in several cases. Some advocated high carbon iron, up to 4.50 per cent carbon, referring to such iron as being made under conditions of high temperature. Under this head the question arose as to the detrimental effect of using coal to recarbonize in the ladle while tapping. It was agreed that coal in large quantities makes gas in the metal, but some contended that the gas was dispelled while the ingot was solidifying.

11—Limestone versus burnt lime. In discussing the relative merits of limestone and burnt lime it was the consensus of opinion that limestone was best. It was claimed that the turbulence caused by the evolving gases (CO_2) when the limestone is calcining is favorable to the elimination of slag inclusions—chiefly silicates—because the stirring causes the fine particles of slag to coalesce and so rise to the surface where they become lodged in the slag, forming calcium silicates. In a discussion outside of the scheduled routine several wide awake men thought that good slag covering the bath, a bottom that is inert, a residual of manganese not below .30 per cent the final deoxidation of the bath with residual carbon, and a uniform continuous stirring of the bath by the evolving CO gas are the primary factors in making fine steel.

12—Pig iron research. Dr. C. H. Herty, Jr. made a tentative report on experiments that are being made with open-hearth heats charged with pig iron running all the way from 1 per cent silicon down to 0.20 per cent silicon. This low silicon was obtained by throwing the blast furnace off its gait. The outcome of the tests will prove of interest when they become available.

The Farrell Foundry and Machine Company of Ansonia, Conn. has designed a new 36 in. two-wheel grinder for quick accurate grinding of rolls not over 36 in. in diameter, that has a new crowning device by means of which a perfect crown is obtained without using any cut and try method. This device in addition to being accurate can be set in a few moments.

The carriage is run to the center of the roll, two nuts are loosened and the scale turned to the desired crown. The nuts are then tightened, a clutch thrown in and the crowning operation is started. The action of the crowning device is perfected by means of a cam acting through lifting rods. The back of the wheel head is raised and lowered and the grinding head pivoted in front of the wheel head. Thus the wheels are moved to and from the center of the roll and produce a perfect crown. Concaving is also accomplished accurately and quickly with this device. If straight grinding is desired the entire device may be disengaged by merely throwing a clutch.

The grinding is performed by two grinding wheels on opposite sides of the roll.

Oxygen in Steel and Non-Hardenability

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therefore reduced to mere traces, though the steel remained oxygen free. This is one of the reasons why chromium steels present usually less difficulties in hardening than straight carbon.

The freedom of steel from the ternary alloy at this stage brings out a very interesting point. A small amount of ferro-chrome added to steel containing only a small fraction of 1 per cent of silicon prevents it from absorbing oxygen, but addition of larger quantities of this substance, up to 18 per cent as in case of some stainless steels, makes possible the saturation of the steel with oxygen with amounts of silicon present which would warrant entire deoxidation of carbon steels. It is not infrequently the case that some stainless steels containing 1.25 per cent silicon contain also 0.08 per cent oxygen, these being, of course, entirely unsuitable for carburizing purposes.

This article was written in order to present a better understanding of the conditions existing in furnace practice which results in unhardenable steel. The point of view taken has been that of a furnace man rather than that of a scientific investigator, consequently many points interesting to the latter were intentionally omitted and the description was limited to the features leading to the production of metal satisfactory for hardening purposes. It may be noted that no reference was made to grain size because any discussion of the conditions leading to the production of small or large-grained steels, while often (though entirely erroneously) associated with their hardenability, belongs to an entirely different field and its treatment here will necessarily interfere with the clearness of the presentation of the main subject.

The tin plate industry as a whole is beginning to recognize the advantages of the wet cleaning of tin plate process as shown by an order placed recently with The Aetna-Standard Engineering Company by one of the largest independent tin plate producers for sufficient machinery to equip their entire mill.

The two outstanding advantages when using the wet cleaning process are: First, economy in operation; and second, increased quality of product.

When this installation has been put into operation, approximately 50 per cent of the tin plate made in the United States will be produced under this process.

Oxidizing Reactions in the Blast Furnace

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was scarcely touched by the blast, and there was very little loss by combustion.

The erroneous assumption that combustion must take place uniformly all over the whole surface of the hearth has led to the tuyeres being placed radially and pointing towards the center of the hearth. This arrangement is precisely the one which gives the largest possible oxidizing zone. By arranging the tuyeres tangentially, the extent of this objectionable zone would be much reduced and better working results obtained. The author has applied for German patent rights for this arrangement. At the same time the furnace may be made cylindrical, or even of the form of a truncated cone, which would lead to further improvement.

Lukens Steel Company's New Plate Mill

Old Type Plate Mill Converted into Efficient Unit by Adding
4-High Finishing Stand and Accessory Equipment of
Modern Design. Rotary Shears Simplified Operations

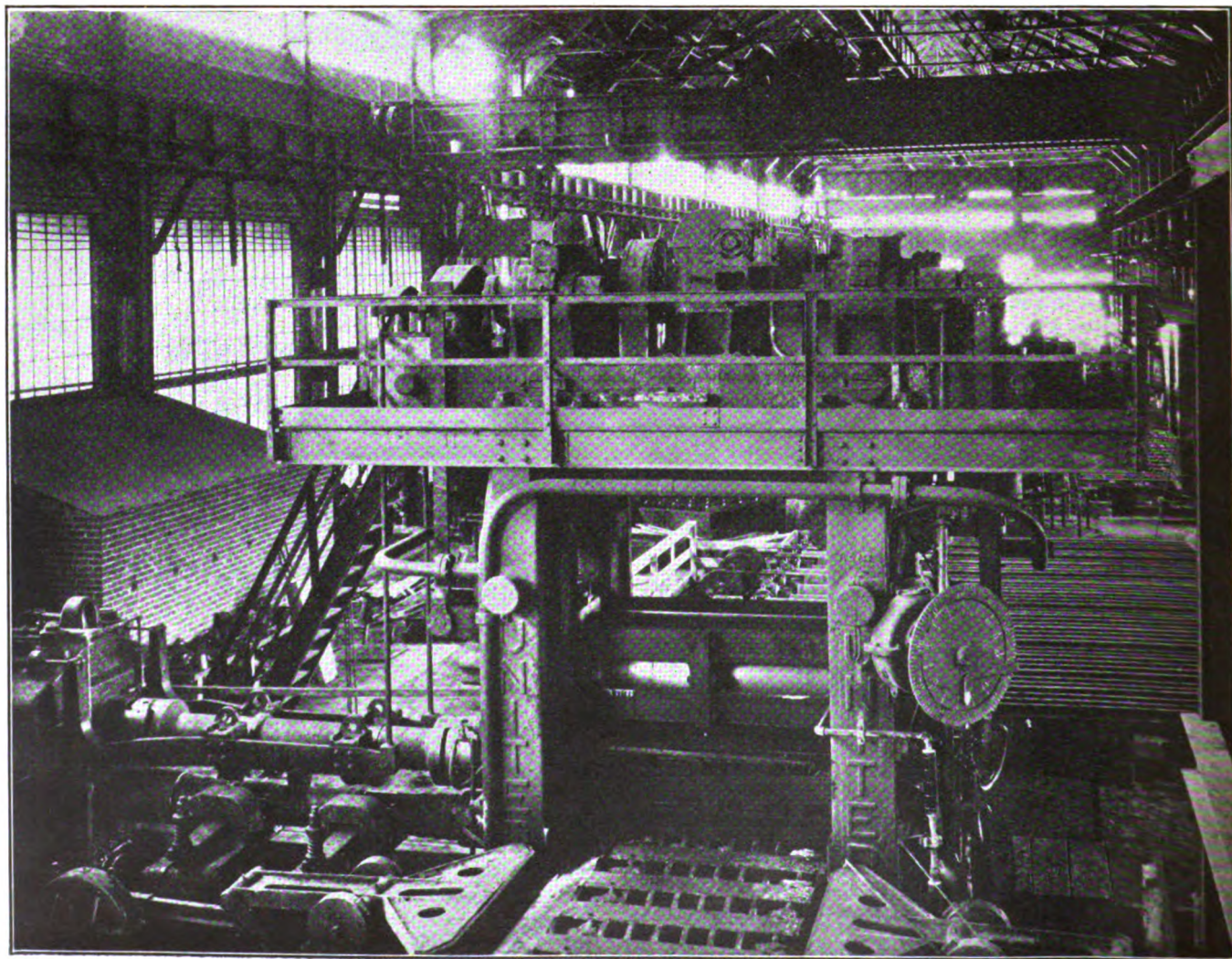
EMBRACING many new and unique features in its design, the Lukens Steel Company at Coatsville, have placed in operation a new 84-in. reversing plate mill. The new mill, designed and installed by the United Engineering and Foundry Company of Pittsburgh, produces plates ranging from 16 gage, 60 in. wide to $\frac{3}{8}$ in. plates 72 in. wide. The complete unit in which this mill is included consists of a 2 high roughing mill, a 4 high finishing stand, transfer tables, roller levelers, annealing furnaces, conveyors, hot bed for inspection and a special type of rotary trimming shears.

The first part of the unit, the roughing mill is a modernization of a former 84 in. hand mill. The mill in being redesigned has been equipped with new differential screwdown and a rollers control which allows him to keep his plate uniform as to thickness at all times.

The second unit of the mill or the finishing stand

is new throughout. It is a 4 high, reversing type, the rolling being done between the two middle rolls and these rolls being supported by the top and bottom backing up rolls, the rolling loads being carried by the necks of the latter. The working rolls are 23 in. in diameter and the backing up rolls 40 in. An innovation was introduced in that the backing up roll necks are equipped with roller bearings. Two important factors result from this innovation; the elimination of heat due to friction found where bronze bearings are used and a great reduction in the power required to drive the mill.

The screwdown is of the differential type, its indicator having two dials, the outer dial being graduated in ten-thousands of an inch and its inner dial in inches. A universal spindle of the gear type drives the top working roll. Double helical tooth pinions installed in a completely closed pinion housing connect up the mill and drive.



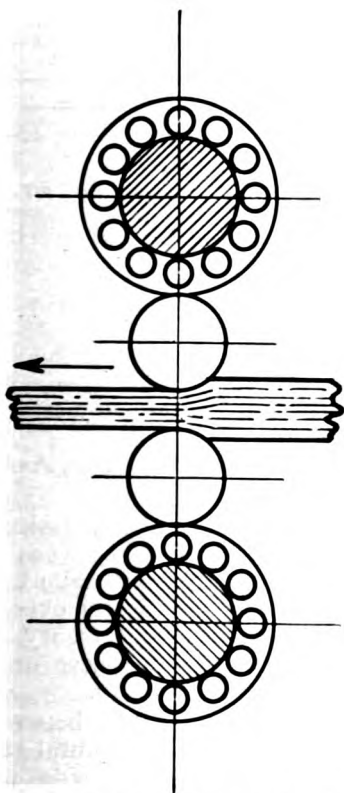
Front view of four-high mill showing dial and screwdown mechanism.

A roll changing rig which greatly reduces the time involved in changing rolls and makes roll changing much easier is another feature of this well designed mill.

Another very important feature of the layout is the design of the various shears comprising the unit. The plates reach the first of these shears after leaving the inspection table. These shears are of the rotary type with two sets of cutting disks which allow both edges of the plate to be cut at one time. The engineering feature of the shears is that the bottom disk on each side is very large and corresponds to a flat block of an ordinary gate shear. The small top disk cuts against a bottom disk, four times as large. This gives good square edges to the sheared plates.

A gate shear is provided for end shearing. The engineering features of this shear is that the shears can be set to a gauge for cutting the plate to length, the plate with parallel edges cut by the rotary shears is held against a side guard at the same time. This allows the plates to be sheared to perfect right angles and exactly to length and width. This is indeed an engineering achievement.

The power for the mill is provided by the most modern electrical equipment. Two large General Electric Company motors of the reversing type operate the two mills. The motors are on direct current.



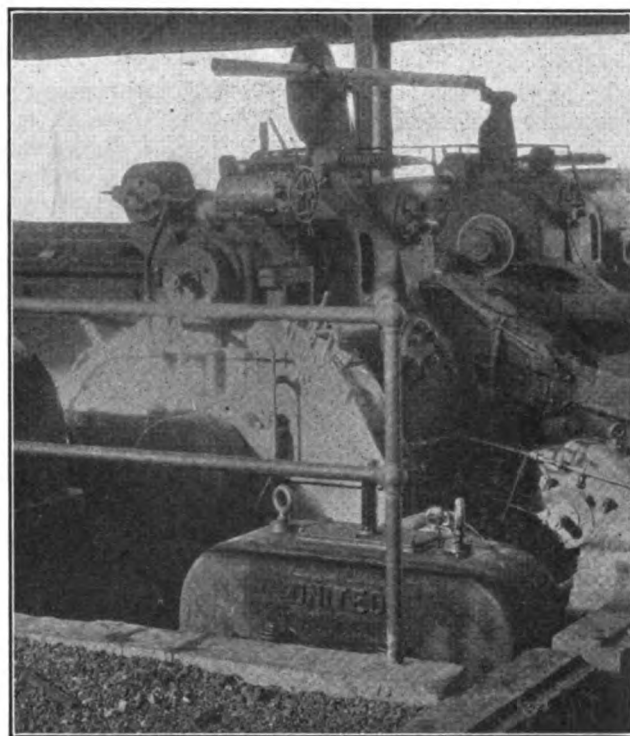
Manner of rolling on four-roll mill.

The auxiliary mill equipment including tables, shears, etc., are electrical driven.

As the product of this mill is both annealed and unannealed plates, a new normalizing furnace of the continuous open annealing type,—oil burning, and in which the furnace temperatures are controlled automatically by thermostats, is included in the new

equipment. This furnace was manufactured by the Costello Furnace Company, Pittsburgh, Pa.

Included in the other equipment are a number of oil heating furnaces for slabs. These furnaces which



View showing rotary shears, especially designed for this mill.

are of the side door type, were built by Wellman-Seaver-Morgan Company of Cleveland, and installed by George J. Hagan Company of Pittsburgh.

No expense has been spared, in incorporating in this new unit every feature that will guarantee not only the highest quality of product, but will allow it to be produced at the lowest possible cost.

Manufacturers of Turnbuckles Consider Simplification

At a preliminary conference of representative manufacturers of turnbuckles, meeting at the Department of Commerce on May 10, 1927, under the auspices of the National Committee on Metals Utilization, steps were taken looking toward formulation of a simplified practice recommendation to cover the standard list of sizes and varieties.

As presiding officer, Mr. P. H. H. Dunn, National Committee on Metals Utilization, outlined the procedure that is followed by the National Committee and the Division of Simplified Practice of the Department of Commerce in their joint effort to co-operate with business to eliminate prevalent, avoidable waste, also giving examples of elimination of waste programs in effect in other fields.

It was the sense of the meeting that a committee should be appointed to conduct a survey of current practice within the industry, and to draw up a tentative simplified practice recommendation. Mr. C. F. Herrmann of the Wilcox, Crittenden and Company, Mr. G. C. Soule of the Marine Hardware Equipment Company, and Mr. E. E. Baker of the Upson-Walton Company were appointed.

Binding for Industrial Furnaces*

The Author Gives the Calculations Required to Provide the
Necessary Strength in the Binding of Furnaces—
Relation of the Binding to Furnace Life

By A. E. PERKINS

AT the present time when so many industrial furnaces are being fired by oil fuel, one hears many complaints regarding the shortened life of brickwork, etc. The writer has had opportunity of inspecting many of these furnaces, and is of opinion that in many cases contributory cause is to be found in inadequate supporting of arches, walls, etc., by inefficient buckstays and tie-rods. It will be obvious to anyone acquainted with such furnaces that they are in many cases stayed and tied by any old section of material that can be secured from the scrap-heap, without apparently any regard for suitability of purpose.

The following notes are submitted to show how a few simple calculations can enable anyone to provide adequate strength to meet the forces that are at work in all industrial furnaces.

Fig. 1 shows the rough outline of a furnace for heating up to 2,000 deg. F. The buckstays are 2 ft. 6 in. apart, and have to assist brickwork walls to resist arch thrust. Weight of a 2 ft. 6 in. section of arch:

$$2.5 \times \frac{9}{12} \left(2 \times 3.14 \times 10 \times \frac{60}{360} \right) \times 125 \text{ lb.}$$

$$= \text{say, } 2,500 \text{ lb.,}$$

and horizontal reaction

$$= \sqrt{3} \times \frac{2500}{2} = \text{say, } 2,200 \text{ lb.}$$

From practical experience it has been found that this figure needs to be multiplied by factors to deal with the expansion due to different temperatures. These have been found to be approximately:

Factor 2 up to 1000 deg. F.

Factor 2½ between 1000 deg. and 1600 deg. F.

Factor 3 between 1600 deg. and 2000 deg. F.

Factor 3½ between 2000 deg. and 2500 deg. F.

In our example we adopt the factor for temperatures between 1600 deg. F. and 2000 deg. F., and the theoretical thrust 2200 lb. is therefore to be multiplied by 3, giving:

$$2200 \times 3 = 6600 \text{ lb. horizontal reaction.}$$

The pull on the top tie-rod will then be:

$$\frac{6600 \times 72}{96} = 4950 \text{ lb. (see Fig. 2);}$$

and allowing a stress of 6000 lb. per sq. in., we require

$$\frac{4950}{6000} = 0.8 \text{ sq. in.}$$

at bottom of thread. Use 1¼-in. tie-rod. The bending moment (B.M.) in the buckstays is

$$\text{B.M.} = \frac{6600 \times 24 \times 72}{96} = 118,800 \text{ in.-lb.}$$

Allowable stress, say, 11,200 lb. per sq. in.; then the required section modulus

$$Z = \frac{118800}{11200} = 10.6.$$

A suitable section can be selected to fulfill this requirement. Some designers use a single buckstay, often of rail section, with a forged end to tie-rod to pass over stay (Fig. 3). The writer prefers to use two R.S.J. or rail sections with the tie-rod in between secured by a casting plate (Fig. 4).

Much of the success of the furnace as regards life will depend on the tie-rods being adjusted when ex-

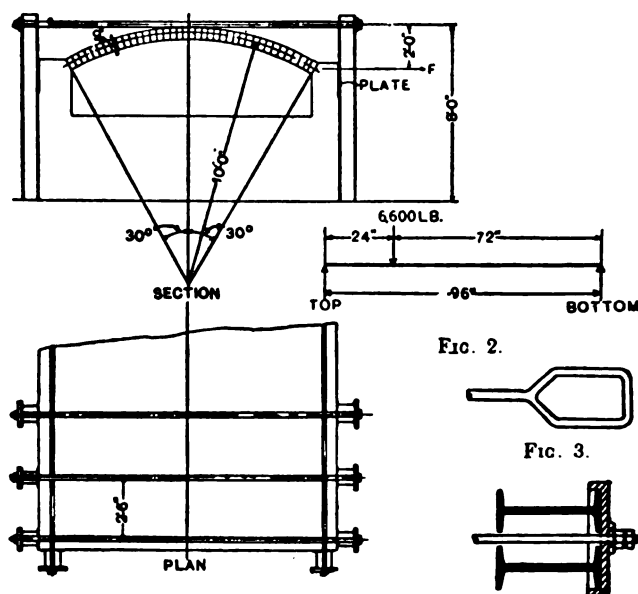


FIG. 1.—STRUCTURAL ELEMENTS OF INDUSTRIAL FURNACES.—FIG. 4.

panding and contracting, and a practice very prevalent in America is to interpose between the nuts and the buckstays a spring that will take care of expansion and contraction automatically over the range of temperature. This is hardly necessary, however, except in cases of very large furnaces or of large and rapid fluctuations of temperature.

A plate banding the furnace between the buckstays and central with the horizontal thrust of arch is usually provided unless the side walls are abnormally thick and are in themselves sufficient to take care of the thrust. This plate should have a section modulus at least 50 per cent to 75 per cent of the total modulus required.

$$\text{B.M.} = \frac{6600 \times 30}{8} = 24,750 \text{ in.-lb.}$$

$$\text{and } Z \text{ required} = \frac{24750}{11200} = 2.$$

*Mechanical World, March 11, 1927.

A plate 24 in. x $\frac{1}{2}$ in. thick would give:

$$Z = \frac{24 \times 0.5 \times 0.5}{6} = 1.$$

and this would do. Some designers, however, prefer a rolled-steel section such as an angle, but this often necessitates cutting the brickwork, which is not advisable.

Gas-Electric Lift Bridge Now in Service

The gas-electric lift bridge built by the Pennsylvania Railroad across the Chesapeake and Delaware Canal during the past year was officially put in operation March 15. This is a railroad bridge over which will travel steam trains running on the Delaware Division of the P. R. R., whose terminals are Philadelphia and Cape Charles.

The new bridge is of the vertical lift type and is located at a point 18 miles south of Wilmington. Previous to the present installation a small swing structure was used but, because of the widening and deepening of the canal and the consequent passage of large boats through it, a bridge of the lift type was found desirable.

At the time the change-over was made, the location was remote from electric power lines, and gas-electric drive was decided upon as being the cheapest method of operation. Complete electrical equipment was furnished by the General Electric Company for this purpose.

Two 110-kw. gas engine driven generator sets and exciters are installed in the operator's house on the shore, together with a switchboard and necessary control devices. Two 120-hp. motors, to operate the bridge, are located in the machinery house on the bridge itself. Flexible cables connect the motors to the power supply on the shore.

Each of the motors is of sufficient capacity to operate the bridge alone, and one of the generating sets is to be held in reserve as a spare. The equipment is so arranged that any combination of generator, exciter and motor can be used.

To open or close the bridge, the gas engine is started first, as the intervals between operation are too long to make continuous running of the engine desirable. By means of a selector switch, the operator next chooses the combination of generator and exciter he will use. The third operation, utilizing manual control, starts the motors, putting the bridge in motion. At the "nearly open" or "nearly closed" position, a limit switch shuts off the power and, to complete the motion, the limit switch is short circuited by a push button and the bridge jogged along to the "fully open" or "fully closed" position.

The bridge itself is of steel construction, built by the Phoenix Bridge Company. The two piers are of stone, reinforced with concrete. The total length of the bridge is 419 ft., and the height of the towers from the ground is 149 ft. 6 in. In the closed position the bridge is 50 ft. above the water and, when open, is raised 90 ft.—or to a point 140 ft. above the water. The bridge carries two tracks and is 37 ft. wide. The lift span weighs approximately 700 tons, and the time required to lift the span to the full clear position is 90 seconds.

Westinghouse Electric Reports Record Year

Sales by the Westinghouse Electric & Mfg. Company for the year ended March 31, 1927, totalled \$185,500,000 and were the largest in its history, exceeding the previous record figure of last year by \$20,000,000. The net income available for dividends, \$16,138,441, was exceeded only once before during the history of the company. The earnings per share of stock (preferred and common) were \$6.80 or 13.8 per cent. Both classes of stock are now receiving \$4.00 per share of \$50 par value.

The company's cash position is also favorable. Current assets total \$120,000,000, whereas the current liabilities amount only to \$18,000,000. Of the current assets, \$72,000,000 consists of inventories, a reduction of more than \$7,000,000 as compared with last year. The value of unfilled orders at the close of the year was \$55,300,000, a slight increase over last year.

"The sales billed for the year," stated Guy E. Tripp, chairman, in his report, "reflects the improvement in operations due to the more efficient use of the manufacturing facilities added during the past two years. The cost of sales reflects the keenness of competition and slightly lowered prices.

"During the year financing operations were effected which reduced the fixed interest charges of the company by approximately \$1,000,000 per annum.

"The volume of sales for export increased over the previous year. Competition for export business continues to be keen, but certain affiliations in the foreign field effected during the year should assist in securing a substantial volume of new business.

"The average number of employees during the year was 47,084. The number of stockholders is 38,469; average holding of shares is 62; and 40 per cent of the stockholders are women."

Steel

The second quarter has brought some slackening in the output of steel. This is a normal seasonal development. Operations at the beginning of May averaged a little under 90 per cent of mill capacity compared with 94 per cent in March. Mills have a good volume of current business and no signs of drastic curtailment are in evidence. During the first quarter of the year, the output of steel ingots was about 2 per cent under that of the like period in 1926. March production of steel ingots totaled 168,000 tons, a new top for all time. Pig iron output in March of 112,300 tons was the third highest for any March on record. Unfilled orders of the United States Steel Corporation in March declined 44,000 tons. This compared with a drop of 236,000 tons in March, 1926.

Lewis Foundry and Machine Company Changes Management

Mr. Frank Cordes, formerly superintendent of the Warwood plant of the Wheeling Mold & Foundry Company, and Mr. J. R. Dunsford, until recently sales manager of the same company, have assumed the management of the Lewis Foundry & Machine Company. Mr. Cordes will act as president while Mr. Dunsford will occupy the position of vice president. The plant of the Lewis Foundry & Machine Company, which is one of the most modern manufacturing steel mill equipment, is located at Groveton, Pa.

The POWER PLANT

*Burning Powdered Coal Under Boilers**

A Recital of the Trend in the Development of the Modern Boiler
Furnace. Influence of Thermal Conditions
on Construction and Design

By HENRY KREISINGER†

THIS paper deals with the development of water or steam-cooled furnaces for burning powdered coal in steam generating units, and points out that these water and steam-cooled furnaces make it possible to take full advantage of turbulent mixing in the combustion space which is necessary for high rates of combustion.

Refractory Lined Furnaces

The early installations for burning powdered coal under steam boilers had refractory lined furnaces which were designed and constructed along the same line as the stoker furnaces of that time. The main difficulties encountered, when burning pulverized coal in such furnaces, were the slagging of the ash and rapid erosion of the fire-brick furnace lining. The ash fused and accumulated in molten or semimolten condition at the bottom of the furnace and was very difficult to remove either hot or when cooled. The removal of such slag required much hard labor and caused frequent outage of the boiler from service.

The ash was sprayed on the hot refractory walls and ran down in molten condition eroding the brick and washing it to the bottom of the furnace. Under such conditions, the fire-brick lining wasted away rapidly and required frequent repairs. The washing away of the brick lining was particularly rapid if the flames were allowed to impinge on it. In order to prevent the impingement of the flames the walls were moved out of the flame by making the furnaces larger than was necessary for nearly complete combustion.

Effort to Prevent Flame Impingement

In the effort to prevent the impingement of flames on the fire-brick lining, the turbulence of the furnace gases was limited to the minimum. The lack of sufficient turbulence made the process of combustion rather slow so that only a small amount of coal could be burned per cu. ft. of combustion space. Usually the rate of combustion was limited to an average of about 2 lbs. of coal per cu. ft. of the entire combustion space, or a rate of heat liberation of about 25,000 Btu. per cu. ft. per hour. This average was low because, in the effort to prevent the impingement of the flame against the furnace lining, the combustion space near the walls was effective to only a small degree.

*Abstracts from paper presented before the International Conference on bituminous coal, Pittsburgh, November 16, 1926.

†Research engineer, Combustion Engineering Corporation.

Hollow Refractory Walls

Efforts to produce, at reasonable cost, refractories that would resist the erosive action of the molten ash, met with little success. The composition of coal ash varies so much that it is difficult to get refractory material that will resist each variation in the ash composition. Air-cooled hollow walls gave some relief, but the problem of erosion was not completely solved.

As the size of the steam generating units was rapidly increasing and the furnace walls had to be built very wide and high (the furnace designer faced the problem of making the walls mechanically strong so that they would not collapse before they were worn out by the erosion of molten ash. The expansion and contraction of such large walls is great, and it is difficult to provide slip joints on such structures.

Water-Cooled Furnaces

During the last three or four years the furnace designer gradually came to the realization that the right way to build a furnace for burning powdered coal was to make the furnace walls of water-cooled or steam-cooled surfaces; in other words, to build the boiler around the furnace. Such metallic walls would be very strong and durable and would also absorb a large amount of heat, thereby relieving the boiler proper of much of the work, and, particularly would relieve the tubes in the first row of the excessive heat to which they are exposed in the refractory furnaces. This is no small consideration these days when boilers are operated at high ratings.

In furnaces equipped with water-cooled walls, the rate of heat liberation may be much higher because the walls will not be damaged by flame impingement and high temperatures; all of the combustion space may be utilized effectively; furnaces and burners may be so designed as to cause intense turbulence of the gases, resulting in more thorough mixing and rapid combustion. In fact, the average rate of heat liberation may be increased up to 40,000 Btu. per cu. ft. of combustion space per hour, with nearly complete combustion. This increased rate of heat liberation permits the use of a smaller furnace.

Fin Tube Furnace Walls

The term, "fin tube" is applied to a specially designed tube of standard boiler size and gage to which have been welded two flat steel bars, or fins, one on each side of the tube. A row of such tubes, when

rolled into a header, makes a practically continuous metal surface. The fins are $1\frac{1}{2}$ in. wide and $\frac{1}{4}$ in. thick. One of the flat surfaces of each fin is exposed to the radiant heat from the flame. This radiant heat is transmitted by conduction to the tube and thence to the water inside of the tube.

Intensive Mixing in Furnace Important

Intensive mixing in the furnace is by far the greatest factor in the promotion of rapid combustion because it brings the oxygen and carbon together. When the two are once brought together, at the ordinary furnace temperature the chemical combination is almost instantaneous. In other words, the rate of combustion is determined by the rapidity with which oxygen and carbon are brought together and not by the speed with which they combine after they are brought together.

The particles of powdered coal although small in size, when compared with the oxygen molecules are still very large. A very large number of the oxygen molecules must be brought in contact with the coal particles before the latter are completely burned. The surface area of the particles is rather small so that only a small number of oxygen molecules can be brought in contact at a time. The products of combustion must be continually removed from the surface in order that a contact with fresh oxygen molecules can be made. Intensive mixing helps to do this.

Furnace Temperature

The temperature above the limit of ignition is of minor importance because it affects directly the rate of chemical combination of oxygen and carbon when the two are brought together. It does not affect materially the mixing or the bringing of the oxygen and carbon together.

It is frequently observed that rapid combustion is accompanied by high temperatures, and the conclusion is sometimes drawn that the rapid combustion is caused by high temperatures. However, the true sequence of the cause and the effect is this: intense mixing causes rapid combustion and rapid combustion causes high temperatures.

With the usual rates of combustion found in steam boiler practice, there is very little danger that water-cooled furnace walls will cause incomplete combustion by excessive cooling of the flame. The temperature of the flame is always high enough for anything to burn that is burnable as long as the supply of air is sufficient and the air mixes properly with the coal particles.

Effect of Preheated Air on Furnace Design

Another factor contributing to the demand for the water-cooled furnace walls is the preheating of the air used for combustion. The practice of bleeding turbines for heating feed-water is growing rapidly. This practice limits the use of the economizer and its place is taken by the air preheater. With the use of preheated air, the furnace temperature is higher, and, therefore, the wear on the refractory furnace walls is greater. Water-cooled furnaces are not damaged by high temperatures and are therefore better suited to the use of preheated air.

Steam Generating Unit at Lakeside Station

In the furnace at the Lakeside station of the Milwaukee Electric Railway & Light Company, the front

wall is made of fin tubes. The arch and upper part of the front wall are protected by plain tubes. The side walls are made of the radiant type of superheater and the back wall of the radiant type reheater. The bottom is cooled with a water screen and the tubes of the boiler form the roof of the furnace.

Steam is generated at a pressure of 1,200 lbs. and is superheated to a temperature of 720 deg. F. It is then expanded in a high pressure turbine to 300 lbs. pressure and 420 deg. F. temperature. The steam from this high pressure turbine is passed through the reheater where it is heated to 720 deg. F. It is then discharged into the main steam line of the plant and is used in the large turbines.

The capacity of the boiler is 240,000 lbs. of steam per hour. The heating surfaces are as follows.

Water-heating surface in furnace ..	1,544 sq. ft.
Water-heating surface of boiler....	28,532 sq. ft.
Total water-heating surface	30,076 sq. ft.
Superheating surface	930 sq. ft.
Reheating surface	933 sq. ft.
Total heating surface in furnace....	3,407 sq. ft.
Air preheating surface	40,320 sq. ft.

Powdered coal is fired vertically downwards through 12 burners. Primary air is supplied under pressure of 15 in. of water, at a temperature of 300 deg. F. Secondary air is supplied through the burners and through ports in the front wall, at a temperature of about 500 deg. F. and a pressure of about half an inch of water.

Rate of Heat Absorption in Furnace

The rate at which the water heating surfaces in the furnace absorb heat, varies from about 20,000 to 60,000 Btu. per sq. ft. per hour and depends on the rate of heat liberation per sq. ft. of surface exposed to radiation. Approximately one half of the total heat absorption by the water takes place in the furnace.

Long Distance Telephone Man Wins National Prize

For noteworthy public service during the Florida hurricane last September, Oscar T. Koon, of West Palm Beach, a section lineman of the Long Lines Department of the American Telephone and Telegraph Company, has been awarded the Theodore N. Vail gold medal and \$500. This is the highest honor bestowed by the Bell System.

It was due to Koon's courage, resourcefulness and devotion that telephone service was so quickly established with Miami following the disaster.

He was in Miami when the hurricane struck. While the wind was still blowing 100 miles an hour, he set out for West Palm Beach to make a report of the damage. He covered the 68 miles partly by automobile, partly on foot. Wrecked buildings, trees and debris blocked the way. His automobile was stopped by 8 ft. of flood water. He was in danger of being swept from his feet by the wind, or of being struck by flying and falling objects.

Koon left Miami about 8 o'clock Saturday morning. He reached West Palm Beach about 2 o'clock Sunday morning. He had had no food since Friday night. He was exhausted, but he reached his goal hours ahead of the newspaper reporter who brought the first press dispatches out of Miami. His report helped greatly in restoring communications and mobilizing relief forces.

A Laboratory Study of Slag Erosion*

The Special Research Committee of the A. S. M. E. on Boiler-Furnace Refractories Reports Progress in Its Investigation on Its Slag Erosion Problem

By SAMUEL J. McDOWELL†

AN investigation of boiler-house refractories is being carried on in a co-operative way by the Special Research Committee on Boiler Furnace Refractories of The American Society of Mechanical Engineers, the Fuel Division of the Bureau of Mines, and the Columbus Branch of the Bureau of Standards. It is the laboratory of this work being carried out at Columbus on which I shall touch today. The work was started while the Columbus Station was under the Bureau of Mines and was admirably outlined by Mr. G. A. Bole who was superintendent. Since July 1 the station has been known as the Columbus Branch of the Bureau of Standards, and the work has been continued with the fullest co-operation existing between the field and laboratory phases.

The work in the laboratory started about a year ago, and two men are employed on it. One is a ceramic engineer employed by the bureau, the other a mineralogist employed by the Special Research Committee. These men have at various times gone out into the field to obtain first-hand information, and the laboratory phase has kept in the closest touch with the field work so that the practical side might be stressed.

Object of the Investigation

The object of the laboratory work was an endeavor to throw light on the very interesting and complicated phenomena known as slagging, the ultimate object being an endeavor to develop laboratory tests which would properly evaluate the resistance of a refractory to a certain slag. It was also hoped, of course, that the work might point to some method of alleviation.

The tests which have been devised and used up to the present time have all been more or less empirical in their nature, and none have found universal application.

One of the early attempts consisted in making cup-shaped depressions in bricks and filling these cups with various slags. The bricks were then given a definite heat treatment, after which they were cut in two and the penetration noted. It was found that this test showed little more than porosity, as the porous bricks absorbed the slag more than the tight-burned ones, regardless of the other considerations.

Other tests have been used where bricks were heated in a furnace and made a target for various slags which were introduced in the gases. This carried the objection that the entire brick was heated and that the effect seemed to be more that of heat than slag action.

The early work of Bleininger and Brown and later work of Wilson and Schroeder consisted of immer-

sing a refractory stick into a slag bath. One objection to this is that the slag attacks the container and changes composition.

Howe Hewitt, and others have done interesting work on the deformation of slag-clay mixtures, but conclude that the method has a limited applicability. Other tests have been devised which allow the molten slag to flow over the face of the brick—and such tests are being used in various forms, but there is little agreement as to the interpretation of results obtained.

The whole question of a suitable slag test has reached such an uncertain state that the American Society for Testing Materials has abandoned its tentative test, which was the cup test mentioned, and now has no specifications whatever, although it recognizes slagging as a major problem.

The reason why proper tests have not been devised is that the fundamental information has not been available upon which to build. Just what happens during the slagging process is not obvious, and only as more light can be thrown upon it can progress be made. It therefore seemed advisable to study the matter of slagging with every available laboratory tool to gain the necessary background, from which it is hoped eventually to develop a test which will simulate service conditions to such an extent that information obtained in the laboratory will check up with plant conditions.

Procedure

There are several ways in which the problem might be attacked. These may be briefly summed up as follows:

1—A thorough study of the thermochemistry involved and the development of equilibrium diagrams covering the various phases present. This is the type of work now being so ably done by the Geophysical Laboratory in Washington. This is an enormous undertaking due to the large number of components present, and we are hardly equipped to undertake it.

2—A continued search by the cut-and-try method for an experimental test which would fill the requirements, taking advantage of the previous mistakes of others. This method without background would not be likely to produce any more results than it has in the past.

3—A systematic study of the most important slag refractory systems, including a microscopic determination of the crystalline materials present and their relation to both glass and refractory, followed by an endeavor to duplicate these results in the laboratory. This procedure, which is really a compromise of the first two, was chosen.

Through the co-operation with the field investigation, samples of brick were sent to the laboratory after their life in service had been studied. Some special mixtures were also made up and fired either in the laboratory or under its control. They were then tested in service and sent in for examination. Most of the

*Presented before the American Refractories Institute, Pittsburgh, Pa., October 21, 1926. Published by permission of the Director of the Bureau of Standards.

†Superintendent, Ceramic Experiment Station, Bureau of Standards.

tests were made in a boiler using Illinois coal, although slag samples were also sent in from furnaces where two different Pittsburgh coals were used under different conditions.

A microscopic examination of an ordinary slagged brick which has been slowly cooled, as we go back from the heated surface shows (1) the slag itself, presumably in the same condition as it was deposited from the gases in the boiler. This consists largely of iron in the form of magnetite or hematite, glass, a lime-soda feldspar, and some mullite. With Illinois coal ash and an ordinary clay refractory, the slag is about $\frac{1}{8}$ in. thick. This gradually blends into (2) the glassy interface. This in reality contains much more crystalline material than it does glass. Here, near the slag, are found grog grains partially dissolved or about to be washed out by the slag. There is considerable mullite in large-sized crystals, some of which seem to have grown from small crystals in the clay refractory to large ones in the slag. There is also some mullite which has actually precipitated from the slag itself. Magnetite and the feldspars are present in minor amounts. The thickness of this material is usually about $\frac{1}{4}$ to $\frac{3}{8}$ in. and grades into (3) the unaltered refractory. This usually shows little crystal structure for a fireclay brick, beyond some grains of quartz and tiny mullite needles in the ground mass.

It will be seen that the action of the slag on the refractory with the formation of these various crystal phases may offer an excellent opportunity for spalling to take place. There is a considerable volume change as some of these crystals are formed, and enormous strains may be set up by a change of only a few degrees of temperature. This has been found to check up with service conditions, and many of the refractories showed cracks developing in or just behind this so-called "glassy" interface as they were removed from the walls, although the fact that the slag is molten at high temperatures tends to make spalling less likely until lower temperatures are reached.

The other usual laboratory tests were made on the refractories. These included load and spalling tests, porosity, specific gravity, deformation, etc., and an effort was made to correlate them. Chemical analyses of the coal ash, slag, etc., were also available from the Fuel Division of the Bureau of Mines.

With these findings as a background, it was decided to start work on the development of a furnace which, it was hoped, would simulate service conditions to such an extent that the same mineralogical conditions could be produced as were to be found in boiler practice. It would then be possible to control such variables as:

- 1—Composition of the slag.
- 2—Amount of slag in gases.
- 3—Velocity of gases.
- 4—Temperature.
- 5—Furnace atmosphere.
- 6—Duration of test.

These variables could then be tested one at a time and their effect noted.

To date, two types of furnace construction have been tried out and another is now being completed. In the first two types the furnace was long and narrow, and the test bricks were placed in the side walls with the burner in one end. In the latest type the walls are permanent, with the bricks to be tested in the arch. In each case a synthetic Illinois coal ash and powdered Illinois coal were introduced in closely

controlled amounts into the air-gas stream, and the flame bathed the surface of the bricks. The powdered coal was used so that it would burn at the surface of the brick and produce local reduction, as would be the case in a boiler. In the later type of furnace there is also a secondary burner impinging on a bed of refractory material in the bottom of the furnace. This heat reflects on the arch, and it is thought it will thus be possible to have the surface of the brick hotter than the gases, as is true in a boiler of the chain-grate type.

The limits of some of the variables in this work have been roughly fixed for our conditions. With the use of any temperature higher than 2,700 deg. F. in the furnace, the refractory seems to be affected more from the heat itself than the slag. One-half pound of coal and slag per hour has been used rather successfully with a neutral furnace atmosphere, although it will be necessary to study the effects in a much more thorough manner after the design of furnace has been finally decided upon. Little has been learned as yet of the other variables.

Microscopic examination has paralleled this furnace development and has shown that there is some similarity between the results obtained and the slag action in service. In one of the tests a water-cooled pipe was run up the rear wall of the furnace and temperatures obtained which varied from 2,700 deg. F. in front to 2,200 deg. F. at the outlet into the flue. A microscopic examination of the slag at these various temperatures and also field samples received, indicate that a fair idea of the temperature to which any coal-ash slag has been subjected may be obtained by the microscope. This is due to the apparent change of the plagioclase feldspar from those high in soda such as oligoclase and andesine at lower temperatures through labradorite and bytownite to almost pure anorthite at temperatures near 2,700 deg. F. and seems to be true whether much or little is present. This is presumably due to the volatilization of soda, and is being further studied as to the effect of other variables. If this is shown by later work to be a function of temperature alone, it will point to very close relation between operating boiler temperatures and slag composition.

Future Work

At the present time the development of the furnace is being continued not so much as a test, although it is hoped this will come later, but as a method of controlling the variable factors. Work is also being started on that portion of the iron-calcium-alumina-silica system in which the usual crystal phases found in slag work fall, as it is felt necessary to obtain this piece of fundamental information before additional progress can be made. The work on the slagged refractories sent in from the field is being kept up to date and the microscopic phase stressed, as it is believed that this tool will throw the most light on this subject.

Later in the investigation when a furnace has been developed which will duplicate service conditions and the effect of the variables is known, and working in connection with the committee appointed by the Refractories Institute, we hope to be in a position to determine the effect of such things as process of manufacture, alumina-to-silica ratio, size of grain, temperature of firing, etc., of the refractory, and later plan to prove our laboratory findings with the installation of panels of brick in commercial boilers.

A Small but Important Factor in Successful Welding

Since a large part of a finished weld made by any of the modern processes of fusion welding represents added metal or metal from the welding rod, the nature of this added metal and the degree to which it merges with the parts to be joined, decide in large measure the success or failure of the weld. Just how much difference the rod itself makes in the speed of welding, strength and uniformity of results is interesting to note.

On a gas-welded steel pipe line recently completed in Southern California, it was found that a slightly lower grade of rod slowed down the progress of the welders by nearly 20 per cent. This represented a totally disproportionate increase in cost. As to reliability of the completed joints, 600 lbs. hydrostatic pressure failed to produce a single leak in any of the joints made with the better quality rod.

If all welding rods were alike, there would be neither danger from the use of inferior or unsuitable material, nor the opportunity for users to profit through recognition of the differences which do exist. To illustrate: If two pieces of cast iron are welded by the oxy-acetylene process with a rod cut from one of the pieces, the resulting weld will lack the strength obtainable with rod designed especially for the purpose. When melted, cast iron suffers oxidation and loses some portion of its original constituents. In its final form cast iron weld metal has a composition quite different from that of the rod. Hence the necessity for rods designed to give the right metal in the weld. Careful study of the changes taking place during fusion forms the working basis for the production of high grade rod. During manufacture the proper quantity of the more volatile elements is added to compensate for the changes that accompany the welding operation.

The bulk of modern oxwelding is done with five types of welding rod; namely, drawn or Norway iron, "high test" steel rod, cast iron, bronze and aluminum. The first of these (preferably copper coated to prevent rust), is used extensively for welding such materials as mild steel castings, structural steel, steel plate, and wrought iron and steel pipe—to mention but a few of its applications. Where still greater strength is desired, high test rod is meeting with great favor, since it works easily and produces joints with tensile strength a full 20 per cent higher than those obtainable with drawn iron rod.

Cast iron welding rod finds its chief application to grey iron castings, from small tools to large machine parts of every description. Where the problems of expansion and contraction become serious and preheating difficult, welding with bronze is proving exceptionally satisfactory. Lower welding temperatures and the soundness of the welds produced make the use of bronze particularly desirable for a rapidly increasing variety of work.

Good rod, of no matter what metal, should work smoothly under the flame, without much variation or noticeable sparking. Rods produced by wellknown and unquestionably reliable equipment manufactures cost a little more than those of uncertain origin. The difference represents insurance whose cost is ridiculously small in comparison with the value of the completed job.

Centrifugal Blowers and Compressors

The first centrifugal turbo-compressor was built in France by Professor A. C. E. Rateau, pioneer in this work. As early as 1904 he had in operation at the Bethune Collieries in France a steam turbine-driven compressor of a capacity of 5,000 cu. ft. per min. operating at a pressure of 95 lb., and at 3,000 rpm. Following the extensive experience of Professor Rateau, the development of a blower having a special form of impeller adapted to high rotative speeds was carried on during more than 15 years of work by Rateau-Battu-Smoot Company of New York City, whose blower and compressor business has been purchased by Elliott Company, of Pittsburgh and Jeannette, Pa.

The development of high speed blowers has made them adaptable to a wide range of capacities. The use of high speed reduces the number of stages in turbines and blowers, and adds to the simplicity of moderate stresses. Suce blowers in the smaller sizes driven by steam turbines, are operating at speeds above 20,000 rpm. Many of these blowers have been direct-driven by synchronous motors at 3,600 rpm., in sizes above 2,000 hp.

The impellers are of the open type, consisting of straight radial blades of alloy steel. In single-stage machines in the smaller sizes, blades are made integral with shaft, the entire rotor being machined from a single forging. For larger diameters the shaft is made with tee slots to receive the blades which are forced in place in a hydraulic press. The impeller blades are tapered, giving uniform stress throughout. This type of impeller eliminates end thrust.

With the works of the former Ridgway Dynamo & Engine Company, the main plant at Jeannette, Pa., and the Turbine Works at Wellsville, N. Y., Elliott Company is prepared to supply complete motor-driven or turbine-driven blowers and compressors, with condensing equipment, gear transmission, and auxiliary apparatus for an entire installation.

Blast Furnace and Steel Plant Appoints Manager of Field Service

H. Milton Reich, for many years in the employ of the Jones & Laughlin Steel Company, has accepted the position of Manager of Field Service with Steel Publications Incorporated, publishers of The Blast Furnace and Steel Plant and Forging - Stamping - Heat Treating. Mr. Reich served for nine years as assistant to the master mechanic of the South Side works, hence he assumes his new duties well posted in steel plant practice. In placing Mr. Reich in this position, Steel Publications Incorporated adheres to the policy of forming its personnel of those who have had steel plant operating experience. As manager of field service he will have occasion to visit many plants, thus affording a means of contact between the editors of the above mentioned magazines and the operating officials.



Selling Methods in the Steel Industry*

Profits in the Sale of Steel Products Are Small Due to Abuses
Which Are Listed—Suggestions Are Offered to
Eliminate Faulty Selling Practices

By CHARLES F. ABBOTT†

WE are in an industry that is especially unfortunate in the matter of profits. It is one of the three most important industries in the world, and yet profits that are being made in it are not in proportion to its vitally fundamental character. We have no less an authority for this statement than Charles M. Schwab, chairman of the Bethlehem Steel Corporation. Not long ago he stated, "The American steel industry has an investment of approximately five billion dollars and the industry as a whole is earning no more than 5 per cent on this investment."

Less than a year ago Eugene G. Grace, president of the same corporation, in making his maiden speech before the American Iron and Steel Institute, said that the steel industry must find a way to increase its earnings on invested capital. He continued, "In the motor industry earnings run 10 to 15 per cent on invested capital, or in some cases higher, but we, meanwhile, are earning only about 4 or 5 per cent."

After all, this condition which exists in the steel industry is no mystery. It is the direct outcome of the methods of doing business that until recently have been employed in this giant industry. I say "until recently," because in the last few years several divisions of the industry have taken steps to eliminate the abuses that have been handicapping the sale of steel.

Let us see if we can catalog some of the abuses. These are five principal ones:

First—There has been a lack of research. The steel industry has done practically nothing, in an organized way, to develop new uses for steel. Most of the important new uses for the commodity were initiated by the users. The automotive industry, for example, came to the steel industry and specified its requirements. And so did the manufacturers of steel railway coaches.

Second—Opportunities have not been followed up. Even when a new use was discovered, little was done to develop it. In other lines of business, as soon as a new way of using a material is found, advertising is immediately employed to tell the world about it. For example, the Bakelite Corporation not only advertises to the many markets using its material, but it also uses advertising to scout for unknown uses.

As a result of this policy, the company has succeeded in numerous instances in getting Bakelite used in place of the following materials: wood, glass, amber, celluloid, fibre, rubber, shellac, gellatin, horn, ivory, jet, metal, paper, porcelain, rawhide, vegetable ivory, etc. That is an example of what research, followed up energetically by advertising, will do.

Third—There is the matter of too much inside competition. As distributors, we have been competing with ourselves and thus letting our real competition,

the manufacturer of substitute materials, make unwarranted headway. Further, the steel producer has not always adhered to policies best calculated to enable steel to meet such competition from substitute products.

I feel somewhat embarrassed in discussing this question before the Concrete Reinforcing Institute as I have but recently been advised of a condition that is drawing a great deal of comment, much to the discomfiture of the structural steel industry.

My attention has been called to an address by O. H. Cheney, vice president, American Exchange Irving Trust Company, New York. The address was delivered in Chicago before the Business Secretaries' Forum on February 16. In the course of his remarks the speaker pointed to the fact that the United States Steel Corporation is contributing a large sum to the fund of the Portland Cement Association. It is, of course, well known that this fund is being used to promote a greater use of reinforced concrete, the principal competitor of structural steel. There is no question but that one of the outstanding effects of the Steel Corporation's contribution is the displacement of a large tonnage of steel. It is rather unfortunate, though not without its amusing aspects, that such a policy should be so freely commented upon by architects, engineers, and others interested in construction.

Naturally, the structural steel industry is placed in a difficult position when the greatest producer of steel is featured as appropriating a large sum to promote the interests of the chief competitor of the steel fabricator. This is all the more the case since no money whatever is being contributed by this producer to further the interests of the industry now producing annually 2,700,000 tons of fabricated steel. As a result of this action, reinforced concrete benefits at the expense of steel. Its consumption is being extended, while structural steel is being displaced and its market circumscribed. There is, however, no comment that should come from me, as those who have assumed responsibility for this contribution undoubtedly feel justified in what they have done.

We must accept the comment that the situation is creating and stand to one side while the public is drawing its own conclusion.

Fourth—There is the abuse that can best be described as topsy-turvy relations. Producers have been foolishly competing with the intermediate or distributing industries—their best customers—by going direct to the customer and, in many instances, underselling the distributor.

Equitable methods of sales and distribution must be adopted and adhered to, otherwise the distributors cannot be expected to function efficiently. Dissatisfaction and suspicion quickly freed destructive forms of competition. The distributing system becomes disorganized. The producer is then left with no alternative but to go direct to the consumer for the major

*Abstracts from address delivered at the annual convention of the Concrete Reinforced Steel Institute, March 21.

†Executive Director of the American Institute of Steel Construction.

part of his business. This is an expensive procedure, an unsatisfactory plan, and in the end a totally ineffective policy.

Efficiency demands a co-operative relationship between the producer and the distributor. They have a common interest and, unless their problems are considered jointly, unless they are worked out through mutual understandings, these problems inevitably accumulate with all their attendant difficulties.

Finally—We have with us, as the fifth and perhaps the most prevalent of all abuses, our horse-trading methods of selling. This situation is due primarily to a lack of a price policy. Steel has always been sold for what it will fetch, rather than for what it is worth or what it cost to produce.

It is to this fifth condition that I am going to devote myself largely in this address, for horse-trading methods of salesmanship are rampant throughout the industry.

Selling Steel

Steel salesmen should use their imaginations to picture the service that their product is going to render when it is in use. Take a bridge, for instance. I do not imagine that I am disclosing a secret when I say that most of our bridges are sold at near cost or at a loss. Let us consider, for a moment, the Bear Mountain bridge, or the mighty steel span connecting Philadelphia and Camden. The economic importance of these bridges is simply incalculable. These structures will serve billions of persons; yet the companies who supply the material that make bridges of this type possible, although they assume great risks, make very little, if any, profit. Can you think of any greater absurdity?

Manufacturers outside of the steel industry, who use steel in making their products, are not so backward in stressing the advantages of steel. There are at least 50 national advertisers today who are featuring steel in their copy. As I was preparing this address, I picked up a copy of the Saturday evening Post, issue of March fifth. The very first advertisement that I saw in that issue was that of a bolt and nut manufacturer whose page is headed "A Miracle of Steel." This manufacturer bases his whole selling appeal on steel.

If those outside of our industry find it to their advantage to capitalize the qualities of steel, how much more should it be to our advantage to emphasize all the qualities of our own product?

The following suggestion was submitted as offering a possible solution:

First—Place all sales emphasis on American made steel, not because of sentimental reasons, but because of a more dependable uniform quality and service. The future of the industry could best be insured by eliminating all elements of chance.

Second—Put in stock a limited supply of foreign material to be used as a medium to force sales of American steel.

Third—If, after exerting every effort to sell the domestic product, utilizing every selling inducement, the customer still was influenced by the lower price, then accept the order and thereby prevent a loss of business.

This plan would, however, result in the customer purchasing the domestic steel in most cases. It would afford the means by which fire could be fought with

fire, instead of standing pat on American steel with no comeback with which to reinforce its position.

The purpose of this advertising can be best stated by citing our creed. It is:

"The structural steel industry is not merely a group of fabricators whose interest in steel ends with its fabrication, sale and erection; for the fabricator's true responsibility is discharged only when his product has been honestly produced, intelligently marketed, and economically used."

The American Institute of Steel Construction believes enough in steel to want to tell the world about it. Through advertising, we hope to invest structural steel with qualities in the minds of buyers that will lift it out of the competitive class to which it has long been subject. We realize that the advertised business is today the only business that can get away from undesirable competitive selling.

You are Invited—

to call at Booth No. 189 when you attend the annual convention of the Association of Iron and Steel Electrical Engineers at Syria Mosque, Pittsburgh, June 13 to 18. There you will be welcomed by members of the editorial board of the publications The Blast Furnace and Steel Plant and Forging-Stamping-Heat Treating.

Welding Society Announces Establishment of the Miller Medal

At the annual dinner of the American Welding Society held in New York on April 28, President F. M. Farmer, announced the donation of an award, the gift of Samuel Wylie Miller, to be presented by the society annually in appreciation of work of outstanding merit in advancing the art and science of welding. The award is a gold medal, which will be known as the Miller medal.

Mr. S. W. Miller has been one of the outstanding figures in the advancement of welding ever since its commercial inception. He is a past president of the American Welding Society, and a prominent and active member of the Society of Mechanical Engineers, American Institute of Mining and Metallurgical Engineers and other scientific and engineering organizations. He has been long noted for his energetic insistence upon high quality and dependable workmanship and upon the development of welding by all processes along lines scientifically well founded. Mr. Miller is consulting engineer, Union Carbide and Carbon Research Laboratories, Inc.

In establishing this award, the details for the administration of which are not yet decided upon, Mr. Miller's object is to promote an appreciation of better welding and to encourage the study of those fundamentals which will lead to raising the quality of work done by the average operator.

In accepting the administration of this award on behalf of the American Welding Society, Mr. Farmer outlined briefly the history and ideals of its donor, and expressed himself as being particularly gratified that during his administration the welding society should be granted the privilege of managing such an important contribution to the improvement of the welding industry.

TRADE NOTES

The Philadelphia district offices of Combustion Engineering Corporation, Heine Boiler Company and Ladd Water Tube Boiler Company have been consolidated at 807 Bankers Trust Building, Philadelphia, Pa.

* * *

Announcement is made by Link-Belt Ltd., that Jackson-Lewis Company, Ltd. Toronto, have been appointed general contractors on the first unit of the building program of the company. The company's property is located at the corner of Eastern Avenue, and Leslie Street, Toronto.

For the past 12 years this company has occupied rented factories, but expansion in their manufacturing lines and in their business has made necessary the purchase of about five acres of land, and the start of their building program.

The unit now in course of construction, will consist of a two-story building, 80 x 160 ft. Of buff pressed clay brick, the walls will be trimmed with Queenston limestone. The supports, of structural steel, are being supplied by McGregor & McIntyre, Ltd., of Quebec.

It should be interesting to note, in this connection that the factories of Link-Belt Company, with subsidiaries, now number 11; its warehouses, 13; and the total number of its branch offices, 37.

* * *

The Prest-O-Lite Company announces the sale of the Storage Battery branch of its business to a new company, Prest-O-Lite Storage Battery Corporation. The entire capital stock of the purchasing company is owned by the Automotive Battery Corporation of New York. That portion of the Indianapolis plant of The Prest-O-Lite Company, Inc., used for the manufacture of storage batteries has been leased to the new company.

The Prest-O-Lite Company, Inc., while discontinuing the battery branch of its business, will continue the manufacture and sale of acetylene gas for use in the oxy-acetylene process of welding and cutting metals, automobile lighting, lead burning, etc.

* * *

William B. Senseman has been appointed Pacific coast district manager for Combustion Engineering Corporation, Raymond Bros. Impact Pulverizer Company, Ladd Water Tube Boiler Company and Heine Boiler Company, all subsidiaries of International Combustion Engineering Corporation.

Mr. Senseman has been associated with Raymond Bros. Impact Pulverizer Company for the past 15 years and since 1917 has represented that organization on the Pacific coast.

The new consolidated offices are located in the Subway Terminal Building, 417 South Hill Street, Los Angeles, Cal.

* * *

Andrews-Bradshaw Company, Pittsburgh, Pa., manufacturers of the Tracyfier, announce the addition to their personnel of Mr. R. N. Robertson, as chief

engineer, and Mr. A. L. Menzin, as director of research.

Mr. Roberston comes from the American Smelting & Refining Company having been with them for the past 20 years. He is a Cornell man, class of 1905. Mr. Menzin was for some years chief engineer of the Tracy Engineering Company, and prior to that, consulting engineer with the Edge Moor Iron Company, manufacturers of Edge Moor boilers. Mr. Menzin is a graduate of the University of California, class of 1907.

* * *

The Detroit Stoker Company, Detroit, announces the appointment of Mr. A. Castello as district sales representative for their Eastern Canada and Montreal, Quebec territories, with headquarters at 915 New Birks Building, Montreal. Mr. Castello is a well known Canadian engineer having served for many years with different railway companies in Canada in the capacity of mechanical engineer and power plant efficiency engineer. Detroit stokers are manufactured at St. Catharines, Ontario, for distribution throughout Canada.

* * *

At the annual meeting of The Timken Roller Bearing Company held at the main plant, Canton, Ohio, on Tuesday April 19th, all the present officers were re-elected for another year. H. H. Timken is president; W. R. Timken, John G. Obermier, Marcus T. Lothrop, H. J. Porter and T. V. Buckwalter, are vice presidents; J. F. Strough is secretary and treasurer, and W. A. Brooks, is assistant secretary. Directors are H. H. Timken, W. R. Timken, Marcus T. Lothrop, John G. Obermier and J. F. Strough. Only routine business followed the election. The financial report of the company was made public several weeks ago.

* * *

E. J. Kulas, president of the Midland Steel Products Company, Cleveland, announced today that his company has obtained exclusive rights to the manufacture and sale of a new automotive brake. Plans are now being perfected for putting this brake into production within a few weeks. It will be manufactured in sizes to fit the popular run of cars on the market.

John Sneed, of Detroit, is the inventor of the new brake, which is known to the industry as Steeldraulic. It is mechanical, self-energizing, and operates internally. It is claimed it will give upwards of 50,000 miles from one set of linings, and furthermore, that it is so simplified in construction as to make it "fool-proof" in the matter of mechanical adjustments. Operating adjustments will be required, it is stated, only after from 15,000 to 20,000 miles of service, because of the simplicity of control and the absence of the usual number of shafts and levers.

Notice

The publishers of The Blast Furnace and Steel Plant and Forging-Stamping-Heat Treating desire to inform their readers of a change in name of the publishing company. Effective June 1, 1927, these magazines will be published by the Steel Publications Incorporated, instead of The Andresen Company. This latter title will no longer appear on, or in connection with these magazines.

TRADE PUBLICATIONS

Bearing the title "The K. S. G. Process," Publication IC-3, of the International Combustion Engineering Corporation, describes the procedure by which coal is subjected to low temperature carbonization under this process. The publication states "that since 1924 a large-sized unit has actually been in commercial operation" in Germany. It also explains the methods employed in carrying out the carbonization and, by photographs and a flow sheet, enables the reader to understand the function of each piece of equipment. Under suitable sub-headings the production characteristics of the process are detailed. Publication IC-2 by the same corporation carries the unique title "500,000 lb. of steam per hour from one unit." It is a description of Unit No. 2 at the Fordson, or River Rouge plant of the Ford Motor Company, made up of a Ladd boiler fired with Combustion Engineering Corporation powdered coal equipment. Both blast furnace gas and powdered coal are burned under (or more aptly "in") this boiler. The publication presents, in interesting form, information concerning the application of modern equipment, which equipment has made possible the generation of such an enormous weight of steam.

* * *

"Handling Things from Where They Are to Where You Want Them," is the title of an illustrated booklet (No. 575) recently issued by the Link Belt Company, 910 South Michigan Avenue, Chicago, Ill. The booklet shows many interesting uses in industry of the company's varied types of elevator and conveyor equipment.

* * *

"United Effort" is the name of the official monthly bulletin of the employees of the United Engineering and Foundry Company of Pittsburgh, Pa. The employees of six plants and of the general offices of the firm co-operate through local associate editors, working under a general editorial committee, to produce this monthly magazine. It is an example of what fine co-operative effort can do toward turning out an interesting employees magazine.

* * *

"Making Markets" is the name of a unique monthly magazine of sales information published by the Sheet Steel Trade Extension Committee, with headquarters in the Oliver Building, Pittsburgh, Pa. The purpose of the magazine is to diffuse information regarding present uses and future possible uses of sheet steel.

* * *

The Edison Lamp Works of the General Electric Company, have recently issued two booklets on lighting. Bulletin LD 155 is a concise dictionary of illumination terms. Bulletin LD 147A, one of a series of bulletins on lighting data issued by the company, is entitled "Lighting for Street Traffic Control." Both booklets are illustrated, and each contains the latest information in its field.

* * *

The Bristol Company of Waterbury, Conn. has issued Bulletin No. 358, "Pyrometer Instruction."

The bulletin gives reliable information as to the installation and care of pyrometer equipment. The information given is of interest to all users of high temperature measuring devices.

* * *

The Link Belt Company has issued an illustrated booklet describing their power hoe. This contrivance is an improved drag scraper that has proven its ability in service to handle and to reclaim, cheaply and quickly, various bulk materials into and out of storage piles. The advantages claimed for the power hoe system are its adaptability to any shape of storage area, its mobility and its minimum installation and operation expense.

* * *

The Riley Stoker Corporation of Worcester, Mass. has just issued a catalogue entitled "Riley Super-Stokers" in which is described in detail the design, construction and operation of their super-stoker. This publication should appeal to those interested in stoker installations where maximum efficiency at high boiler ratings is required.

* * *

W. A. Jones Foundry and Machine Company, of Chicago, Ill., manufacturers of power transmission machinery, have recently issued a second edition of their No. 26 spur gear speed reducer catalogue. Persons interested in this booklet, may secure one by addressing the company.

* * *

The Metal Equipment Company, 2033 W. 106th Street, Cleveland, O., has just issued a catalogue "C" describing their electric heat treating furnaces. A special bulletin on continuous electric furnaces is also available. Copies may be had upon request.

COMING MEETINGS

June 6-9—American Foundrymen's Association 31st annual convention will be held at the Edgewater Beach Hotel, Chicago.

* * *

June 13-18—Association of Iron and Steel Electrical Engineers annual convention and iron and steel exposition at Syria Mosque, Pittsburgh. Headquarters, 706 Empire Building, Pittsburgh, Pa.

* * *

June 20-24—American Society for Testing Material annual meeting at French Lick Springs. Headquarters, 1315 Spruce Street, Philadelphia.

* * *

September 19-23—American Society for Steel Treating. Annual convention at Convention Hall, Detroit. Headquarters, 4600 Prospect Avenue, Cleveland, O.

The Timken Roller Bearing Company will occupy Space No. 58 at the Iron & Steel Exposition at Pittsburgh, June 13-18. A feature of particular interest will be a steel mill roll neck bearing such as has been developed for, and successfully applied to, both cold roll and structural mills.

A Record Shipment of Rolling Mill Machinery

One of the largest shipments of rolling mill machinery on record recently made from this district again emphasizes the supremacy of Pittsburgh's industries. The shipment consisted of a continuous rolling mill of 15-roll stands and gear reduction drives which was designed and built by the Mesta Machine Company and shipped from their plant at West Homestead, Pa., to the Bethlehem Steel Company's plant at Sparrows Point, Md., where it will be put in operation.

This mill will be installed directly following a 46-in reversing blooming and slabbing mill which was also designed and built by the Mesta Machine Company and was put in operation last year. The complete unit, consisting of the blooming and slabbing mill and the continuous mill recently shipped, will produce slabs, blooms, sheet bar, skelp and strip steel direct from the ingot in one heat; or in other words, without the necessity of reheating during the rolling process. The power required to operate the continuous mill at its maximum capacity will be 25,000 hp. and for the blooming and slabbing mill 20,000 hp.; making a total power requirement of 45,000 hp. for the complete unit.

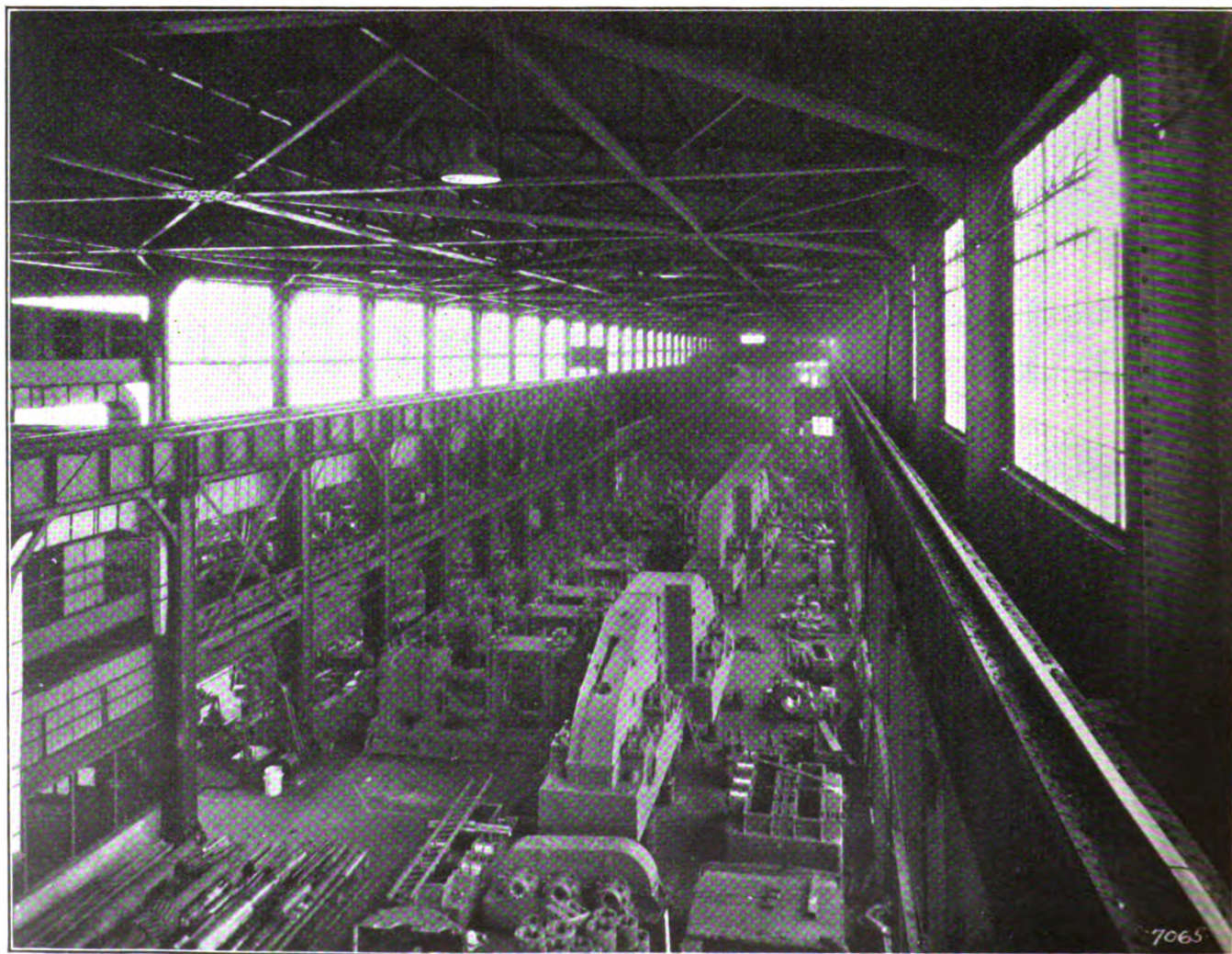
The magnitude of this equipment can be further visualized by the fact that the maximum size of ingots rolled by the blooming and slabbing mill weigh 44,000

lb. An ingot of this size is rolled into slabs; the maximum size of slab produced being 60 in. wide by 24 in. thick. These slabs are sheared into suitable lengths by a mammoth shear and transferred to another mill where they are rolled into plates.

The ingots rolled by the blooming and slabbing mill, which follow through on the continuous mill, weigh about 15,000 lb. each. These ingots will be reduced in the blooming and slabbing mill to 8 in. by 8 in. cross section for sheet bar production or to 7 in. x 22 in. cross section for the production of wide skelp and strip. The 8 in. x 8 in. or the 7 in. x 22 in. billets, as the case may be, will be further reduced in the continuous mill to sections approximately $\frac{1}{8}$ in. x $7\frac{3}{4}$ in. minimum for sheet bar and $\frac{1}{8}$ in. x 24 in. minimum for skelp.

The product emerges from the continuous mill in a reduced form at a speed of 1,300 lineal ft. per min. It will be sheared while traveling at this speed by a new type electrically operated flying shear into merchant lengths varying from 15 ft. to 33 ft. as may be required. One ingot reduced to its minimum size on this mill will make a strip of steel $\frac{1}{8}$ in. thick, $7\frac{3}{4}$ in. wide and nearly a mile in length.

The bars, after being sheared into proper lengths, are piled mechanically by a bar piling machine which is located directly in line with the mill. They are then removed from the bar piling machine by a crane.



Mill equipment assembled in Machine Shop.

Some Notes on Open Hearth Refractories

Comparison is Made of Different Refractories for Banks and Bottoms—Relative Spalling Resistance of Various Brick, Their Non-Corrosion Properties

By B. M. LARSEN*

THE subject of open-hearth refractories may be said to resemble that of the weather, in that we "talk about it much more than we do—." However, it is one of these complex and eternally unsolved problems, and certain factors mentioned here are often overlooked in the many articles written on the subject.

The hearth and lower sidewalls of an open hearth should probably be considered separately from the rest of the furnace structure. The former are in direct contact with a liquid phase of steel or slag, while the latter portions are in contact only with a gas phase in which the only corrosive agents are the very fine oxide fumes or dust particles that are given off from the bath and carried about suspended in the gases.

Hearth Zone—Changes During Service

The ideal basic furnace hearth would probably be a dense, non-porous body of pure magnesia, recrystallized into one solid mass. Such a hearth would slowly corrode at the slag line, but the bottom should last almost indefinitely without patching. It would of course be almost impossible to form such a hearth in a commercial furnace, because temperatures of around 3,100 to 3,400 deg. F. or higher would probably be necessary to sinter and recrystallize the magnesia into a mass sufficiently solid so that it would not disintegrate and float up through the steel, and would not soak up a large amount of liquid slag and iron oxides from the bath. Because the softening point of the silica roof limits temperatures to below about 3,050 deg. F., it becomes necessary in making a bottom to mix some slag with the magnesia to form a liquid phase which helps to bond and recrystallize the magnesia into a fairly solid mass.

At best, the bottom will be somewhat porous and as soon as steel-making begins, slag and iron oxides (chiefly FeO from the steel) begin to fill in the cracks and pore spaces. The more dense and well-bonded is the original bottom the less fluxes it will absorb and the more resistant it should be to disintegration. Wear of the bottom seems to occur chiefly by disintegration by crumbling or penetration or concentration of fluxes along certain planes. Portions tend to crack away and become loosened and then float up through the steel to the slag layer.

The banks are worn away simply by surface corrosion by the slag, and perhaps to some extent by mechanical erosion. This occurs with almost any refractory material used in this zone, although the rate of wear is lower with patching material that is dense and can be sintered together into a more solid, less porous mass.

Refractories for Banks and Bottoms

Banks can be patched with various grades of magnesite, chromite, or dolomite. Although these vary

in resistance to slag corrosion and erosion, they are all worn back fairly rapidly at the slag line, so that the cheapest material is usually the best for commercial use. As a rule this turns out to be ordinary double-burned dolomite, although this is probably less resistant to solution by the slag than the other materials.

Various grades of special "fluxed clinkers" are on the market as patching materials. These are essentially double-burned dolomites with perhaps 10 to 15 per cent of fluxes (usually combinations of Al_2O_3 , Fe_2O_3 , and SiO_2) added before burning, so that the clinker already contains fluxes which tend to sinter the lumps together quickly on the banks of the furnace. Ordinary double-burned dolomite really has the defect of being too refractory and can be sintered into a dense mass on the banks only by combination with the furnace slag remaining on the banks or formed in the next heat. The few data available indicate that certain of the fluxed clinkers are superior, and if they can be marketed at a relatively small increase in cost over double-burned dolomite they should receive much wider use in commercial open hearths.

For bottoms, dolomite, chromite, and magnesite have all been used successfully. Comparison between them is difficult, because the qualities of the materials themselves seem to be less important than the method of making and patching a bottom. Any one of them, if made into a bottom that is fluxed and burned into a dense, solid mass will give better service than one of the others in a poorly burned bottom.

Magnesite is not fluxed very badly by either basic open-hearth slag or by fluxes containing essentially FeO and Fe_3O_4 from oxidation of the steel. Highly siliceous slags, however, will corrode magnesite very rapidly. For example, if a heat is tapped from a very hot furnace with the silica roof and sidewalls "dripping," the slag formed running down on the magnesite hearth will cut deep "canyons" where the streams of siliceous slag runs together over the banks and bottom.

A partial equilibrium probably exists between the upper layer of the bottom which is saturated with FeO and the steel bath containing variable amounts of FeO, depending on its composition. For example: If a furnace making ingot iron is changed to making rail steel, the first few high-carbon heats will tend to be over-oxidized, due to the absorption of FeO from the bottom.

Wear Effects on Roof Arch, Walls, and Port Ends

Upper sidewall, arch, and port surfaces are worn away by spalling, fusion, and flux corrosion. During the patching periods between heats the inner zone of the brick cools from around 2,900 deg. F. down to 1,800-1,900 deg. F., and is heated again rapidly to 2,600-2,700 deg. F. when the flame is turned on for the next heat. The brick around doors are rapidly cooled and heated from currents of cool and hot gases

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when doors are opened and closed. In sprung arches, the expansion on heating causes a high pressure between the inner ends of the brick. All these conditions contribute to spalling effects.

Simple fusion occurs only with silica brick, when the latter are heated above a minimum softening range of about 2,975 to 3,025 deg. F. This sometimes results from a general overheating of the furnace chamber, causing all or a large portion of the roof surface to "drip" or "sweat." Often, however, small local areas in an arch or wall will be badly burned, due to impinging of flame or hot gases, caused by poorly designed or poorly constructed ports and burners, or the "fishtailing" of flame from a high pile of scrap.

Very little slag from the bath reaches the brick surfaces in upper sidewalls, arches, and port ends, and yet these surfaces are slowly worn away by flux corrosion. This action is caused by tiny oxide particles from the bath which are so small that they are easily carried about in suspension in the combustion gases. These particles are mainly iron oxide (usually 80 to 90 per cent Fe_3O_4) with some lime and small amounts of MnO , MgO , etc. At steel-making temperatures, liquid steel has an appreciable vapor pressure (calculations indicate a value of about 1 mm. at 2,910 deg. F.). Iron vapors are continually formed from the bath which are oxidized and condensed to form "fumes" of Fe_3O_4 (approximate composition) and these are carried around to the brick surfaces. Some oxide particles also appear to be formed by the spitting action on surfaces of steel scrap as the charge melts in contact with oxidizing gases.

Port end wall and checker brick surfaces get most of these oxide fluxes because they are directly in the path of the main stream of gases from the flame above the bath. Eddy currents, however, carry some flux particles to all of the roof arch, sidewall and port surfaces to cause a slow but steady fluxing action of the brick in these zones. It is worth remembering that the formation and diffusion of these corrosive oxide particles is not affected by furnace operation, and is an inevitable result of the essential nature of the open-hearth process.

Silica Brick

A new silica brick is essentially a mass of interlocking silica crystals with about 25 to 30 per cent of open pore space. Placed in a roof arch, as soon as steel-making begins, the inner end of such a brick immediately begins to absorb oxide particles from the gases. These particles combine with silica to form a fluid slag which seems to be drawn up into the open pores of the brick by capillary attraction, causing recrystallization and flux saturation of the hot end of the brick to a depth of 4 to 5 in., while a peculiar zone structure is formed. This process is usually complete by the end of the first week or ten days of a campaign. The inner zone of the brick is now a dense mass of cristobalite crystals with 10 to 12 per cent of closed pore space and a softening point at from 2,975 to 3,050 deg. F. It can absorb no more fluxes so that corrosion products now form at the inner surface and drip off into the bath or run down the sidewalls, and the brick is slowly worn away.

The fact is not always recognized that as long as a silica arch is not heated above a maximum temperature varying in the range of about 2,950 to 3,050

deg., the inner zones probably remain quite rigid and are not in a softened condition. A silica brick is really a skeleton structure of interlocked silica crystals. The pore spaces between these crystals are filled with a limited amount of fluxes, mainly Fe_3O_4 and CaO , which will dissolve only a limited amount of the silica crystals at a given temperature. The brick structure remains rigid until the fluxes have dissolved nearly all the interlocked crystals, and this does not seem to occur until the inner layer of brick reaches a temperature around 2,950 to 3,000 deg. F. As long as furnace temperatures are below this range, the brick is worn away only by surface corrosion by fluxes; above this range, more rapid wear occurs by softening or fusion of the brick.

Magnesite Brick

The well-known spalling tendency of magnesite brick is essentially what prevents their use in roof arches. They can be used in vertical sidewalls, but such application has proven practical only in backwalls of tilting furnaces, where it is almost necessary to use something else than silica brick. If a magnesite brick with a spalling and high-temperature load resistance approaching that of silica brick could be developed, the open-hearth refractories problem would be nearly solved.

The patented "Metal-kase" brick or shapes represent an attempt to obtain a magnesite body with increased spalling resistance. The steel cases support and hold the magnesite in place and are supposed to oxidize at the hot ends and react with the magnesite to bind the inner zone of the wall into a solid mass. These shapes have been most successful when used in port end walls opposite the outgoing ports, which are directly in the path of the outgoing gases carrying oxide particles in suspension. Such walls should have a high resistance to corrosion by fluxes and a fair spalling resistance. Silica brick are rapidly corroded in these walls. Metal-kase shapes give much improved service life, as the temperatures in this zone of a furnace are really high enough to melt away the steel cases rapidly. In sidewalls of the melting chamber these shapes have not always given much better results than ordinary magnesite brick, though several operators report very satisfactory life for Metal-kase backwalls. In this zone of the furnace, temperatures are high enough to melt away the steel cases at the heated ends of the shapes. Especially where a new wall is heated up rapidly, the cases are likely to be melted back from the ends, leaving $\frac{1}{2}$ to 1 in. of magnesite core unsupported to eventually spall away.

A new magnesite brick has recently been put on the market. It contains short lengths of iron wire distributed at random all through the brick, and these tend to prevent the cracking away of spalled pieces. These brick have given rather promising results in a few cases, but have not yet been tested enough to indicate their true value.

Chrome Brick

Chrome brick seem to have two points of superiority over ordinary brick: (1) a lesser tendency toward spalling, and (2) a much greater resistance to corrosion by siliceous slags. Magnesite and chrome both seem to resist about equally the corrosion by lime and iron oxide slags, but highly siliceous slags seem to attack magnesite much more severely. For

(Continued on page 300)

The Gas Permeability of Refractory Brick Used in Metallurgical Furnaces*

The Factors Investigated as Affecting Permeability Were Pressure, Type of Brick, Temperature, etc.—Ways are Suggested for Reducing Permeability

By F. A. WICKERHAM†

ENGINEERS and plant executives, who have made a study of fuel conservation, are familiar with the fact that a large amount of heat is lost in industrial furnaces through leakage of gases through the brickwork of the furnaces. This leakage is generally attributed to poor construction of the walls, bad joints between the bricks, or cracks in the brickwork. Few realize to what extent the heat losses are due to actual passage of gas through the bricks themselves.

The leakage of gas through bricks may be easily demonstrated by a few simple tests. If a small funnel is placed against one face of certain kinds of ordinary refractory bricks and a tight seal is made around the edges of the funnel with paraffin, it is possible, by blowing through the funnel, to blow out a lighted match or candle with one's breath. It is also possible to blow smoke from a cigar through the brick, while ordinary fuel gas may be blown through and ignited on the opposite side. Fig. 1 shows a brick with gas burning on one face after passing through the brick.

The passage of gases through bricks is not, as most people believe, entirely due to intercommunicating openings or pores in the bricks themselves. The openings do have their effect, but the flow of gases is also dependent on a kind of diffusion, or what may be called Osmotic effect.

The investigation of the gas permeability of bricks was started as a result of a study of the heat losses in an open-hearth furnace, particularly in the flues and regenerator chamber walls, or that portion of the furnace below the floor level. The open-hearth furnace at best is only about 18 per cent efficient, and any reduction of heat losses will immediately show up in a saving in fuel. In this study it was developed that in addition to the air drawn in through the saucer of the air valve, almost 100 per cent excess air was being drawn in through the walls and flues between the air valve and the furnace proper. A similar condition was found on the out-going end, the volume of waste gases being almost doubled between the furnace and the stack.

This meant that the furnace was being operated under conditions that would require considerable excess fuel. On the in-coming end there was so much air passing through the regenerators it was impossible to preheat all the air to the desired degree of preheat. On the out-going end, the hot waste gases were diluted to such an extent that they were unable to heat up the regenerators to the desired temperature.

*Paper read before the American Iron and Steel Institute, at New York, May 20, 1927.

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The brickwork in this furnace was in particularly good condition. Before making the test, all apparent cracks were carefully sealed, and the furnace put in as good shape as possible. While some of the leakage was no doubt due to cracks that could not be seen or poor joints, it was apparent that some must be due to leakage through the bricks in the wall.

A study of the literature on the gas permeability of bricks showed that the work most frequently cited was a paper read by S. Wologodine before the London Congress of Applied Chemistry in 1909.

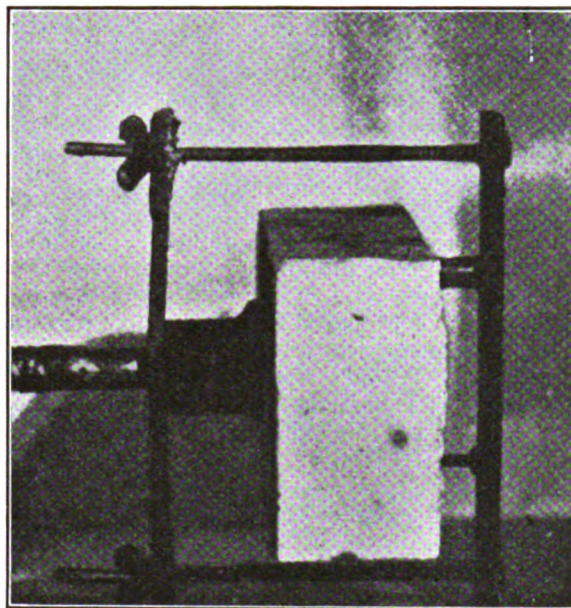


FIG. 1—Gas burning on face after passing through brick.

Recently work of a similar nature has been carried out at the Engineering Experiment Station, University of Illinois, and at the Tohoku Imperial University in Japan.

The present investigation was made to try to imitate in a practical way what might be expected of bricks in actual service. The objection may be raised that the investigation was not scientifically accurate, but it is believed the results obtained would be closely approached under actual service conditions. With a few exceptions, the work was carried out on full size bricks taken at random from the stock on hand.

The Investigation

It was not proposed that this investigation should cover a study of the actual heat losses in various kinds of furnaces due to leakage of gases. Its purpose was to determine the gas permeability of the

ordinary bricks used in furnace construction, with a view of providing means to prevent or reduce the loss of heat due to passage of gas through the brick walls.

A number of different problems are involved in such a study, among which are the following:

Effect of Area of Brick Exposed to Gases and Effect of Extent of Exhaust Area

The results with different areas exposed to gas are shown in Table A.

TABLE A
Effect of differences in area of brick exposed to gas.

Kind of Brick	Area of Exposed Surface of Brick Sq. In.	Time in Seconds for 1 cu. ft. of Free Air at $\frac{1}{2}$ -lb. Pressure to Pass Through Brick
Standard silica brick, $2\frac{1}{2}$ " thick.....	1	439
Same brick	10	135
Standard silica brick, $2\frac{1}{2}$ " thick.....	1	290
Same brick	10	92
Standard silica brick, $2\frac{1}{2}$ " thick.....	1	320
Same brick	10	103
Standard silica brick, $2\frac{1}{2}$ " thick.....	1	293
Same brick	10	89

The results show there is considerable variation in the permeability of different bricks of the same kind, but when the test is made on the same brick, the time required for 1 cu. ft. of free air to pass through different exposed areas varies inversely as the square roots of the exposed areas.

The extent of the exhaust area on the opposite side of the brick also has an influence on the time required for a given amount of gas to pass through a brick.

When a brick prepared by the regular method for testing was immersed in water and air passed through the brick, the bubbles appearing on the uncoated face of the brick indicated that the air was fairly evenly distributed over the whole surface, and did not pass through a relatively small area directly opposite the surface exposed to the air. To determine the effect of area of exhaust surface, tests were made on the same bricks, in which the exhaust area was gradually decreased by coating with paraffin. The results are given in Table B.

TABLE B
Effect of area of exhaust surface on rate at which air passes through bricks.

Kind of Brick	Area of Exhaust Surface on Opposite Side of Brick	Time in Seconds for 1 cu. ft. of Free Air at $\frac{1}{2}$ -lb. Pressure to Pass Through 1 sq. in. of Exposed Surface of Brick
Standard silica brick, $2\frac{1}{2}$ " thick.....	36	405
Same brick	18	445
Same brick	9	475
Same brick	$4\frac{1}{2}$	534
Same brick	1	668
Standard silica brick, $2\frac{1}{2}$ " thick.....	36	335
Same brick	18	350
Same brick	9	362
Same brick	$4\frac{1}{2}$	546
Same brick	1	546
Standard fire clay brick, $2\frac{1}{2}$ " thick....	36	930
Same brick	18	1014
Same brick	9	1082
Same brick	$4\frac{1}{2}$	1215
Same brick	1	1572

The results show that the area of the exhaust surface has a considerable effect on the time required for 1 cu. ft. of free air to pass through a brick. Lack of uniformity in the structure of different parts of the same brick has probably had a marked influence on the results and it does not appear to be possible to establish a law covering the relation between different exhaust areas.

For this reason, tests made on bricks of the same thickness but with exhaust areas of different size are not comparable. With a few exceptions noted, all the work in this investigation was carried out using an exhaust area of the full 9 in. by $4\frac{1}{2}$ in. face. Where exhaust areas of other sizes were used, the comparisons are made between bricks with the same exhaust area.

Effect of Differences in Pressure

Gas pressures in ordinary industrial furnaces with a few exceptions, such as the blast furnace and hot blast stove, are low, varying from a few tenths to a few inches of water column. This is particularly true in such parts of the furnaces as would be effected to the greatest extent by leakage of gases.

Preliminary tests at different pressures showed that the time required for 1 cu. ft. of air to pass through the same brick at different pressures bore a fairly constant relation. These tests also showed that at low pressures a long time would be required to complete one test, particularly on bricks of certain kinds.

As it was desired to test as many bricks as possible in a minimum time, the pressures used in this investigation were higher than those ordinarily found in service. Most of the work was done at 1 lb. or $\frac{1}{2}$ lb. pressure, depending on the character of the brick. Tests were also made at $\frac{1}{4}$ lb. pressure to determine certain features.

The time required for the gasometer to exhaust 1 cu. ft. of free air into the atmosphere at pressures of 1 lb., $\frac{1}{2}$ lb. and $\frac{1}{4}$ lb. was 9.3, 13.3 and 18.7 seconds respectively. The time varied inversely as the square roots of the pressures.

This same relation did not exist when the air was passed through bricks. Table C gives the results of tests made on different kinds of bricks.

TABLE C
Effect of differences in pressure on time required for air to pass through bricks.

Kind of Brick	Time in Seconds for 1 cu. ft. of Free Air to Pass Through Brick per sq. in. Exposed Area		
	1 lb. Pressure	$\frac{1}{2}$ lb. Pressure	$\frac{1}{4}$ lb. Pressure
Standard 9" silica brick, $2\frac{1}{2}$ " thick—A.	161	321	632
Standard 9" silica brick, $2\frac{1}{2}$ " thick—B.	154	300	604
Standard 9" silica brick, $2\frac{1}{2}$ " thick—C.	157	319	633
Standard 9" silica brick, $2\frac{1}{2}$ " thick—D.	232	467	912
Standard 9" silica brick, $2\frac{1}{2}$ " thick—E.	238	476	943
Average	188	376	745
Chrome brick, $2\frac{1}{2}$ " thick—A.....	98	201	395
Chrome brick, $2\frac{1}{2}$ " thick—B.....	171	331	652
Chrome brick, $2\frac{1}{2}$ " thick—C.....	199	392	775
Chrome brick, $2\frac{1}{2}$ " thick—D.....	176	342	670
Chrome brick, $2\frac{1}{2}$ " thick—E.....	187	362	718
Average	166	326	642
Magnesite brick, $2\frac{1}{2}$ " thick—A.....	546	1075	2142
Magnesite brick, $2\frac{1}{2}$ " thick—B.....	630	1256	2496
Magnesite brick, $2\frac{1}{2}$ " thick—C.....	462	928	1850

Magnesite brick, 2½" thick—D.....	547	1074	2140
Magnesite brick, 2½" thick—E.....	448	890	1795
Average	527	1046	2081
Std. 9" fire clay brick, 2½" thick—A	472	920	1780
Std. 9" fire clay brick, 2½" thick—B	532	1024	2005
Std. 9" fire clay brick, 2½" thick—C	501	980	1984
Std. 9" fire clay brick, 2½" thick—D	641	1266	2510
Std. 9" fire clay brick, 2½" thick—E	978	1950	3884
Average	625	1228	2433

While there was considerable lack of uniformity in the results obtained at any given pressure on different bricks of the same kind, when a comparison is made of the time for 1 cu. ft. of air to pass through the same brick at different pressures, the results are approximately inversely proportional to the pressures. Numerous other tests at 1 lb. and ½ lb. pressure showed approximately the same relation.

Relative Permeability

Tests on different kinds of refractory bricks, such as silica, chrome, magnesite and fire clay, gave the results shown in Table D.

TABLE D

Relative rate at which air passes through different kinds of refractory brick.

Kind of Brick	Time in Seconds for 1 cu. ft. of Free Air to Pass Through 1 sq. in. Exposed Area of Brick	
	1 lb. Pressure	½ lb. Pressure
Standard 9" silica brick—A.....	161	321
Standard 9" silica brick—B.....	154	300
Standard 9" silica brick—C.....	157	319
Standard 9" silica brick—D.....	232	467
Standard 9" silica brick—E.....	238	476
Average	188	376
Standard 9" chrome brick—A.....	98	201
Standard 9" chrome brick—B.....	171	331
Standard 9" chrome brick—C.....	199	392
Standard 9" chrome brick—D.....	176	342
Standard 9" chrome brick—E.....	187	362
Average	166	326
Standard 9" magnesite brick—A.....	546	1075
Standard 9" magnesite brick—B.....	630	1256
Standard 9" magnesite brick—C.....	462	928
Standard 9" magnesite brick—D.....	547	1074
Standard 9" magnesite brick—E.....	448	890
Average	527	1046
Standard 9" fire clay brick, 1st quality—A	472	920
Standard 9" fire clay brick, 1st quality—B	532	1024
Standard 9" fire clay brick, 1st quality—C	501	980
Standard 9" fire clay brick, 1st quality—D	641	1266
Standard 9" fire clay brick, 1st quality—E	978	1950
Standard 9" fire clay brick, 1st quality—F	1514	2996
Standard 9" fire clay brick, 1st quality—G	470	936
Standard 9" fire clay brick, 1st quality—H	870	1725
Standard 9" fire clay brick, 1st quality—I	734	1450
Standard 9" fire clay brick, 1st quality—J	1038	2062
Average	775	1531

The first quality fire clay bricks showed a greater variation among themselves than any of the other varieties, but the average time for air to pass through these bricks is higher than for the other kinds of bricks.

Chrome bricks are dense, fine grained and, if judged by appearance only, would probably be considered to be fairly impervious to gases. The results,

however, show that the chrome bricks were the most permeable of the four kinds of bricks tested.

This indicates that the number of pores or openings, their size and intercommunication are not the only factors, but that the diffusion, previously referred to, plays an important part.

Fig. 2 shows a comparison of the size of particles between a chrome and fire clay brick.

Relative Permeability of Fire Clay Bricks of Different Brands and Effect of Process of Manufacture

The silica, chrome and magnesite bricks tested were all from the same manufacturer. No comparative tests were made with the same kind of bricks made by other manufacturers.

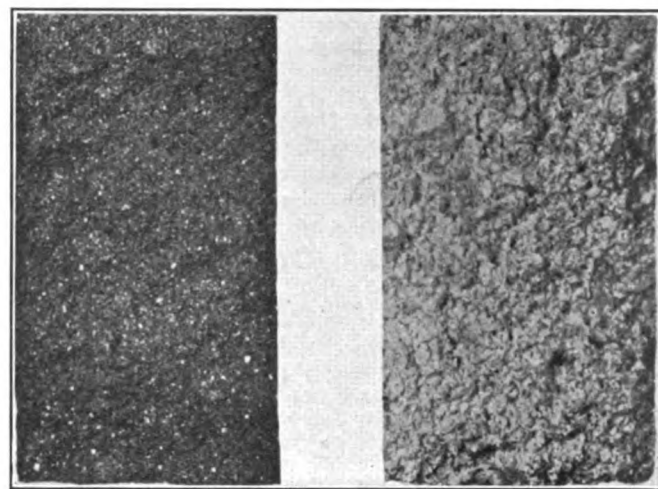


FIG. 2—Comparison of size of particles in a chrome and a fire clay brick.

The fire clay bricks were of different brands from the same manufacturer, also brands from other manufacturers, and covered several different methods of making the bricks. The results are given in Table E.

TABLE E

Relative permeability of fire clay bricks of different brands, and effect of process of manufacture.

Kind of Brick	Brick Maker	Brand	Process of Manufacture	Time in Seconds for 1 cu. ft. of Free Air at 1 lb. Pressure to Pass Through 1 sq. in. of Exposed Area of Brick
First quality fire clay	W	A	Hand made—repressed.	472
First quality fire clay	W	A	Hand made—repressed.	470
First quality fire clay	W	A	Hand made—repressed.	870
First quality fire clay	W	A	Hand made—repressed.	642
First quality fire clay	W	A	Hand made—repressed.	347
Average				560
First quality fire clay	W	B	Dry pressed	1525
First quality fire clay	W	B	Dry pressed	1176
First quality fire clay	W	B	Dry pressed	734
First quality fire clay	W	B	Dry pressed	1038
First quality fire clay	W	B	Dry pressed	1378
Average				1170
First quality fire clay	W	C	Auger mach.—repressed	Imperivous
First quality fire clay	W	C	Auger mach.—repressed	36616
First quality fire clay	W	C	Auger mach.—repressed	7840
First quality fire clay	W	C	Auger mach.—repressed	Imperivous
First quality fire clay	W	C	Auger mach.—repressed	4322
Average				

First quality fire clay	Z	D	Hand made—repressed.	501
First quality fire clay	Z	D	Hand made—repressed.	978
First quality fire clay	Z	D	Hand made—repressed.	695
First quality fire clay	Z	D	Hand made—repressed.	401
First quality fire clay	Z	D	Hand made—repressed.	728
Average				661
Fire clay ladle brick.	R	E	Auger mach.—wire cut	25312
Fire clay ladle brick.	R	E	Auger mach.—wire cut	14741
Fire clay ladle brick.	R	E	Auger mach.—wire cut	Impervious*
Fire clay ladle brick.	R	E	Auger mach.—wire cut	19116
Fire clay ladle brick.	R	E	Auger mach.—wire cut	5040
Average				32816
Fire clay ladle brick.	S	F	Auger mach.—wire cut	35280
Fire clay ladle brick.	S	F	Auger mach.—wire cut	16520
Fire clay ladle brick.	S	F	Auger mach.—wire cut	4556
Fire clay ladle brick.	S	F	Auger mach.—wire cut	11564
Average				20147

*Hard burned.

The results show that the process of manufacture has a considerable effect on the permeability of bricks. Bricks from different manufacturers made by the same process do not show great differences in their average permeability. As an example, the average permeability of hand made repressed bricks "A" made by manufacturer "W," compare favorably with brick "D" made by the same process by manufacturer "Z."

Bricks made by any of the processes show considerable variation in the rate at which gas will pass through them. The hand made repressed bricks are more permeable than any of the others. The auger machine repressed first quality fire clay bricks show the greatest variation in permeability. When bricks of this type are well made, they are practically impervious to gas. Examination of the structure of auger machine repressed bricks, which were permeable to a certain degree, indicated that laminations or slight shattering in the process of manufacture was responsible for the easier passage of the gas through the brick.

Considerable variation in permeability was also shown by the ladle brick of the same brand, but there was not much difference between the two brands.

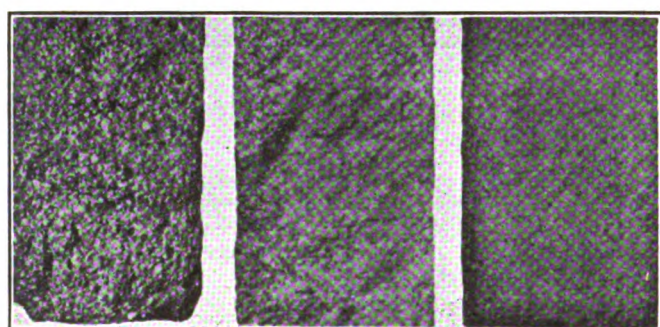


FIG. 3—Comparison of structure of a hand made-repressed, a dry pressed, and an auger machine-repressed brick.

The variation is due to lack of uniformity in the bricks. When the ladle bricks are well made and well burned or almost vitrified in character, there are no intercommunicating openings between the particles and the bricks are impervious to air. Some of these bricks were not burned as hard as others, or a certain amount of shattering of the brick in the course

of manufacture left small openings through the brick which permitted the passage of gas.

Fig. 3 gives a comparison of the structure of a hand made repressed, a dry pressed, and a brick made by auger machine and repressed. It is apparent to the eye that the hand made brick is more porous and offers greater opportunity for gas to pass through it than the other brick.

(To be continued)

Fire Bricks Made of Cyanite

An investigation of the properties of brick, made of cyanite, a fire-resisting material, has been partially completed by M. S. Freed, research associate for Henry A. Golwynne at the United States Bureau of Standards. The material was taken from a recently discovered deposit in India and much of it contains over 95 per cent pure cyanite. Cyanite, either raw or calcined, pure, or bonded with clay, produced refractory bodies capable of withstanding standard and modified laboratory tests for high-grade refractories. The bodies showed excellent resistance to spalling and to deformation under load at high temperature. They also showed a uniform and low thermal expansion and a high melting point. Petrographic analyses indicated complete conversion of cyanite to mullite in the test specimens and the results of the laboratory test indicate the bodies to be the equal in equality of many so-called "super-refractories" now on the market.

Some Notes on Open Hearth Refractories

(Continued from page 296)

example: Suppose that two backwalls are used, both with the upper half built of silica brick, but with the lower half of one made of magnesite and the other of chrome. During service, the silica brick corrode and fuse away, forming high-silica slag which flows down over the lower half of the wall. In this case, the magnesite brick will be badly worn away, especially near the contact with silica, while the chrome brick will be relatively free from corrosion.

The higher spalling resistance of chrome brick is lowered by certain changes during service, so that the brick do not always resist spalling much better than magnesite when used in vertical open-hearth walls. The inner ends of chrome brick in a wall become soaked with fluxes in much the same way as silica brick, but in the chrome brick the fluxes tend to form a glassy, vitrified body which often cracks away under changes of temperature, leaving inner zones exposed to the same action. This flux saturation and spalling at the hot ends seems to be the essential cause of deterioration of chrome brick used in a vertical wall.

All chrome brick are made from natural ores (chromite), and brick made from different deposits (which are very irregular in size and are widely separated geographically) often show wide variation in spalling and load resistance. Even the best brick seem to have some tendency to soften and squeeze out under load at high temperature. The brick are heavy, and a high wall section often causes enough load on the lower courses to slowly deform these brick enough to endanger the stability of the wall.

Chrome brick have been used quite successfully in port end walls and for portions or all of the backwalls in many open-hearth shops.

Shrinkage of Fire Clay Refractories

A Brief Presentation of the Reasons for the Contraction of Refractory Shapes. Quantity of Moisture, Fire Grinding, Burning, Etc. Determine Degree of Change in Size

By M. C. BOOZE*

SHRINKAGE is a factor of considerable importance in the manufacture and use of fire clay refractories. It is generally looked upon as a necessary evil in the manufacturing process and is not stressed in any of the common tests for burned products. That reduction in shrinkage to a minimum and its control will result in savings is evident to a manufacturer upon little thought. The desirability of low shrinkage or lack of shrinkage from a quality standpoint will also become evident when a careful study is made of the behavior of fire-clay brick under various conditions of service.

It is sufficient for our purposes to consider that shrinkage comes from two causes only; first, the evaporation of mechanical water or water of plasticity as it is usually called; and second, the drawing together of individual solid particles due to surface tension of glass formed under heat from impurities present in the refractories or deposited upon them in the furnace. Shrinkage from the first cause comes during drying and from the second during initial burning and in use. The manufacturer is concerned with both kinds and the user only with the second.

Drying shrinkage takes place through the evaporation of surface films of water around individual particles of clay and through the removal of water by evaporation from colloidal or jell-like material which forms part of the clay substance. The latter material can be "set" by heat with almost complete loss of plasticity, as in thoroughly calcined clay. Its behavior is also influenced very greatly by certain salts and acids which may either be present in the clay originally or may be purposely added.

Moisture Content and Fine Grinding

However, in fire clay bodies containing relatively large quantities of flint clay, calcine, sand or other non-plastic material, the fineness of grind and the water content have more influence on drying shrinkage than any other factors. The finer the grind, the greater the number of individual particles in a unit mass and the larger the amount of water required to produce a molding consistency. The large amount of water required for the finely ground clay is accounted for by the fact that a large number of fine particles present a much greater surface to be coated with water than the same weight of coarse particles. The evaporation of this water results in greater shrinkage in the finely ground material than in the coarsely ground.

The great influence of grind upon shrinkage does not seem to be generally understood nor taken advantage of. In a previously published report it was shown that the linear drying and burning shrinkages of coarse and fine flint-plastic clay mixtures varied from 4 per cent for the coarse to 7 per cent for the

fine grind. The screen analysis of these mixtures was about as follows:

	Coarse %	Fine %
On 4 mesh	27	0
Through 4 mesh on 10 mesh.....	23	9
Through 10 mesh on 20 mesh.....	10	16
Through 20 mesh on 40 mesh.....	8	17
Through 40 mesh on 60 mesh.....	4	7
Through 60 mesh on 80 mesh.....	2	4
Through 80 mesh on 100 mesh.....	1	2
Through 100 mesh	30	45

A variety of mixtures showing similar results were described in the same report. In each case the difference is appreciable on both drying and burning shrinkage.

While for various reasons it is not often feasible to purposely vary the grind materially from the established standard, the above data shows if nothing else the importance of maintaining the grind uniform by control tests in order to reduce variations in size.

While the water content has an appreciable effect upon drying shrinkage it has been found through tests made at a number of fire-clay brick plants that the percentage of water is maintained remarkably constant merely by judgment of the pan tender or pug mill operator and that this is not ordinarily a cause for much variation. A small variation in water content has such a large effect upon consistency of the mud that any appreciable change is usually detected readily. However, it is often the case that one molder prefers and is supplied with mud noticeably stiffer or softer than another molder in the same plant. This of course results in varying shrinkages.

An increase in water content is not always accompanied by an increase in shrinkage of the same order. Part of the additional water may result in increased porosity either through crowding some of the coarse particles farther apart and these not being pulled back together during drying, as in a poorly tempered mud, or through the formation of small drying cracks.

Flint clays, unless finely ground, have little or no drying shrinkage, while semi-flint clays have considerably more and plastic clays a maximum of drying shrinkage. The relatively coarse flint particles in a fire clay brick or shape are coated with the finer particles of bond clay and shrinkage of the coating is opposed by the non-shrinking flint clay pieces. The plastic bond seems to be somewhat elastic and if the non-plastic particle is not large the coating will adhere and dry without cracking. However, when the flint or non-plastic particles are as large as $\frac{1}{4}$ in. in diameter and there is a relatively small amount of fine non plastic present, crazing or cracking of the bond around the large particles takes place. This is frequently seen on many brick and shapes. It can usually be corrected by the use of from 20 to 30 per cent of finely ground grog or calcine. Flint clay would often serve the same purpose if properly ground. The latter material, however, sometimes

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becomes partially plastic itself when ground fairly fine and so does not produce the desired results as far as crazing is concerned.

Effect of Burning

Burning shrinkage is affected by the characteristics of the clays used, the grind, the manner of setting in the kiln, and by the burning treatment.

Some clays burn dense at a comparatively low temperature, others become dense only at high temperatures, and still a third class retains a porous structure and shows little shrinkage with any practical burning treatment. Clays of the second class, usually high in alumina, present greater difficulties in manufacturing than either of the others. Those of the first class form strong, tough bodies, but usually have a tendency to deform in the kiln and to spall in service. The third class of clays is the most desirable for many purposes, although with these there is always danger of after-contraction when used at very high temperatures.

The effect of grind upon burning shrinkage has already been noted. It is usually held that a coarse grind is responsible for an "open" or porous brick and vice versa. This is not necessarily true, nor is it believed to be true in very many cases as a study of the report previously referred to will indicate. In fact, some of the values cited show the coarser bodies to be the denser. Since shrinkage on like bodies and under similar conditions will depend to a considerable extent upon porosity, it is therefore not always true that coarsely ground brick will shrink more in service than finely ground products despite the usual belief to the contrary.

It is fairly well known that the shrinkage in burning is affected by the load supported in the kiln and is not the same in all directions. A large thick block carrying no weight is frequently larger on the bottom than on the top, even though uniform when placed in the kiln. Under such conditions it is remarkable that cracks are not more frequent than they are, and this is probably accounted for by the fact that clay refractories are partially plastic even at low temperatures and yield to the unequal stresses instead of cracking.

While the effect of burning treatment upon shrinkage is well understood, the knowledge is not always put into practice and many "half-baked" brick are still turned out. The trend for some time has been toward harder burned products and it is the writer's opinion that this will proceed very much farther than the general practice to day. It is also believed that the manufacturing economies and increase in quality which may result from the promiscuous use of thoroughly shrunk clay grog or calcine have been overlooked, due perhaps to difficulties in finding an efficient method for producing such material.

Shrinkage is certainly an important cause for the failure of fire clay refractories in service. It is affected in service only by furnace temperatures and their duration and so may be controlled only by such drastic means as have been employed in some central power stations. While it is regrettable that no really indicative test for this property has been developed, a real start in this direction has been made by the Refractories Fellowship at Mellon Institute and it is probable that such a test will be available within a relatively short time.

Manufacture of Refractory Shapes

By Ronald A. Malony*

To the average person the word "refractories" has a rather vague meaning, but in the gas industry it suggests a class of material that is second to none in importance. In fact it has been said of the English gas industry that "the profits are made in the retort settings." The same might be said of the American gas works, if the generator linings were also included.

Refractories form the chief materials of which all retorts and gas generators are made, as well as flues and pipes through which the hot gases are conducted. The first cost of refractories is considerable, but aside from this the cost of the labor involved in removing the old and replacing the new, as well as the time lost in making these changes is sufficient to warrant a most careful check of the materials purchased for this important service.

No class of modern engineering materials can claim a more ancient origin than refractories. It was back in the midst of the long Stone Age that someone discovered that the pieces of clay used to wall in his fire became burnt and hung together, and, stranger still, water had no effect upon them. Mankind had acquired a new material, which was later destined to become almost indispensable in the life of ancient man. The discovered remains of his crude baked clay articles oftentimes furnish us with our only clue of his mode of existence. From that time on man has continued to improve his clay products until we reach the amazing perfection of Chinese and European pottery.

While perfection was being attained in pottery, its allied industry, the making of refractories, was content to progress slowly, and it was not until the last twenty years that any real attempts were made to improve these products by the application of modern research. In fact most of this work was accomplished in the last ten years. At the present day, however, the full importance of research is realized, and we find such agencies as the Mellon Institute of Pittsburgh, the United States Bureau of Mines and Geophysical Laboratories, as well as a score of industrial laboratories actively engaged in refractory research. One of the foremost of these industrial laboratories is the one maintained by The U. G. I. Contracting Company. Much of the pioneer work in refractories testing has been developed at this laboratory.

A refractory may be defined as a substance which is infusible at the highest temperature it may be required to withstand in service. This definition is not complete however, because the fact that a substance is infusible does not alone determine its value as a refractory. An almost infusible brick, for example, may be so fragile as to be worthless, since bricks are generally required to support a load in addition to resisting the effects of great heat.

A perfect refractory would meet the following requirements at any temperature:

- 1—It would not fuse or soften.
- 2—It would not crumble or crack.
- 3—Its contraction and expansion would be extremely small.
- 4—It would be impermeable to gases and liquids.
- 5—It would resist mechanical abrasion.

*U. G. I. Contracting Laboratory.

6—It would not react chemically with substances in contact with it.

7—It would either be a very poor or a very good conductor of heat. (In a water gas set the ideal refractory would confine all of the heat to the inside of the generator. In a coal gas retort, however, the direct opposite would apply. A perfect retort would conduct all of the external heat to the coal contained inside to effect carbonization.)

Needless to say, an absolutely perfect refractory has never been developed. There are, however, a number of substances which closely approach these requirements at the temperatures used in gas making. Fire clay and silica are the two substances used most extensively in gas works practice as refractories.

Fire clay is found in all sections of the United States, although Pennsylvania is the chief producer, with Missouri second. In the south, Georgia is the leading state, and, due to its enormous deposits of raw materials, it will probably sometime lead the world as a refractory producer.

The formation of clay is caused by the slow disintegration of feldspathic (granite like) rocks. The constant weathering of the ages has separated the feldspar and the quartz from the mica and the other rocks which made up the granite. The quartz, after being freed, remains in small particles, and we see it today as the chief constituent of sand. The feldspar was decomposed still further by the elements, separating out the small quantities of potash and soda, and leaving behind a material which we call clay. This substance is made up of extremely small crystals—in fact they are so small that if a quantity is placed in water it will remain suspended for days and even months before settling out. The presence of salt in the water would hasten the settling action just as river water when flowing into the ocean deposits its suspended clay a short distance from the mouth of the river, forming the so-called delta.

Pure clay, technically known as kaolin, is a combination of silica, alumina and combined water. Its chemical formula is $\text{Al}_2\text{O}_3 \cdot 2\text{SiO}_2 \cdot 2\text{H}_2\text{O}$. Proportions by weight according to this formula are: alumina (Al_2O_3), 39.45 per cent; silica (SiO_2), 46.64 per cent; combined water 13.91 per cent. This material is white in color, but pure clay is seldom found in nature. Common clay is gray, because of the presence of organic substances. It generally contains iron, which is what gives a common brick its ordinary red color. Pure clay or kaolin is very hard to fuse. It melts at 3272 deg. F. Because of this heat-resisting quality a clay which has the approximate composition $\text{Al}_2\text{O}_3 \cdot 2\text{SiO}_2 \cdot 2\text{H}_2\text{O}$ is called "fire clay." There are six types of fire clays found in the United States, viz; flint, semi-flint, plastic diaspores, kaolins and bauxitic fire clays.

Flint fire clays are extremely hard, and do not become plastic when mixed with water. It is usually necessary to bond them with plastic fire clay.

The semi-flints possess characteristics of both flint and plastic fire clays. Many of them are self-bonding. Their fusion point, however, is lower than that of the flint clays.

Plastic fire clays are the soft clays generally used as a bond for the harder clays. Their fusion point is comparatively low.

Diaspores are a class of super-refractories, having a fusion point above the flint clays, and possessing the characteristic of being self bonding.

The kaolinitic clays are equal or above the flint clays in fusion point. They are always self-bonding, and may also be classed as super-refractories.

The bauxites have a fusion point comparable to the diaspores, and, while self-bonding, they are never used alone, due to their high fire shrinkage.

The impurities in clays are alkalies due to undecomposed feldspar, sand, gravel, iron oxide, silicate or sulphide, calcium and magnesium silicates or carbonates, titania and organic matter. Of these impurities the basic oxides are most harmful, as they lower the fusion point decidedly. This is due to the fact that aluminum silicate combines with bases forming double silicates. For this reason oxides of potassium and sodium render a clay useless as a refractory when present in anything but very small amounts.

The refractory properties of a brick depend to a large extent on the nature and amount of impurities and the ratio of silica to alumina.

Manufacture of Fire Clay Bricks

Fire clay is obtained from the deposits by mining. Most refractory clays in Pennsylvania are associated with the coal measures. The clay is mined either by the open pit process, using steam shovels or by shaft mines.

There are a number of methods employed in moulding, depending on the shape of the refractory and the service required of it. Most special shapes must be hand moulded. Wooden moulds, on which shrinkage allowance has been made, are filled with mud, and, after slicking the surface, the shape is dumped on a pallet and allowed to dry. Upon being dried, clay begins to shrink, and continues to do so during the burning, when the combined water is driven off, and the brick becomes hard. Thus a brick 9 in. in length after being burned, may measure from $9\frac{1}{2}$ to $9\frac{3}{4}$ in. when moulded, depending on the mixture used. Calcined or clay already burned is employed in the mixtures to control the shrinkage. Once burned the brick ceases to shrink, and permanently loses the property of plasticity, which latter fact would indicate that the plasticity is due to combined water.

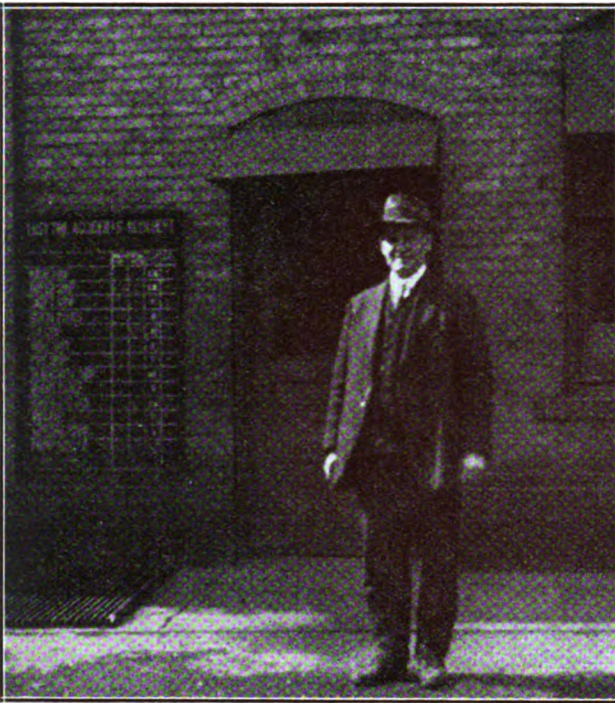
Standard 9 in. bricks may be machine moulded. After the bricks have been thoroughly dried, they are placed in kilns and burned at high temperatures (2200-2450 deg. F.) for from seven to 10 days. In the newer plants producer gas is used to effect the burning process. The kilns are cooled slowly, allowing the brick to become thoroughly annealed before it is shipped to the consumer.

The manufacture of silica refractories is much the same as that of fire clay. Quartzite rock, containing a high amount of silica, is used in the manufacture. This rock is found abundantly in Pennsylvania, Wisconsin and Alabama. Silica differs from fire clay in the respect that it expands when burnt. It is, therefore, necessary to burn these bricks at a very high temperature (2750 deg. F.) in order to remove most of this permanent expansion before they are placed in service. Lime or fire clay up to about two per cent is used in silica bricks for a binder.

Gases or vapors have little effect upon silica, although it is affected by slags.

The question is often asked why it is necessary to have such a large variety of grades and types of refractories. The answer to this is simple. It is not possible to use a single type of fire brick exclusively any more than it is possible to build a business entirely from engineers or accountants.

Well Known Mason Superintendents



PETER ISLES

Homestead plant of the Carnegie Steel Co., Munhall, Pa.



J. C. GARBETT

National Tube Co., McKeesport, Pa.



R. C. SMITH

American Steel Foundry, East St. Louis



"BILL" ISAACS

Youngstown Sheet and Tube Co., Youngstown, O.

Troubles of the Furnace Builders with Refractories*

The Conditions that Exist in Certain Types of Furnaces are Considered Together with the Character of Refractories that Will Meet these Conditions

PROGRESS in the development of furnaces depends as much upon the development of refractories as the progress of the automobile industry depended on the development of the alloy steels so widely used today. Furthermore a need for scientific precision is beginning to make itself felt in the refractories field similar to that which has been discovered in metallurgy. Engineers have available exact knowledge of the properties of steels of definite compositions and they are able to choose the steel most suitable for a given purpose. They can buy steels of these definite compositions according to definite specifications with confidence. This is far from the case with refractories, at least as far as it concerns that portion of the furnace field to which this paper applies.

From the point of view of a manufacturer of refractory it may appear that the sales possibilities for refractories in the steel industry for use in blast furnaces or open hearth furnaces are much greater than in the field of automatic heat treating furnaces, but this will not be the case for the manufacturer who can give us the refractories that we need.

Large automatic furnaces involve many considerations other than that of refractories for example conveyors, combustion principles and automatic controls but 90 per cent of the troubles are directly due to the refractories.

In some cases we can now build these furnaces in a manner that will eliminate these refractory troubles but at the expense of good operation and efficiency.

I can probably best utilize the time available by presenting specifically three representative types of installations.

- 1—Underfired normalizing furnaces.
- 2—Enameling furnaces.
- 3—Brass melting furnaces.

General Factors Applying to Each of the Three Types

The two primary functions involved in the use of refractory materials are those of thermal insulation, and conduction. In some cases the refractory material must have considerable strength at high temperatures and in others great strength is unnecessary. However, we have been using the same refractory material both in those positions where a good thermal conductor was required and where a refractory with strength was needed. In other words, we have been using silicon carbide or carborundum not only in the hearth, but also in the face of the side wall and in the piers supporting the hearth.

Now we suspect that each refractory due to its own individual properties can be used for certain

jobs to better advantage than any other refractory. However, we do not believe that any one refractory can be best in all three of these positions, that is, in the hearth, in the side walls, and in the piers.

We have almost come to the point of believing that it is impossible to tell what a refractory material will do in a given furnace without actually trying it out. The standard tests do not seem to be sufficient.

Perhaps the standard tests are sufficient if properly used or perhaps new tests must be devised which will give us the information needed.

Now, the performance of a given refractory depends, first of all, upon the fuel used in the furnace. Our experience has been confined mainly to the use of oil and gas. We find in general that a certain type refractory stands up better in an oil furnace than in a gas fired furnace. Just why this is we do not know. One of the important factors is that small combustion tunnels are used in connection with gas burners. These tunnels consist of course, of refractory materials, embedded in the refractory lining. Combustion takes place in these tunnels, and the furnace lining is brought up to temperature by the evenly distributed high temperature flue gases. In the oil furnaces, combustion is not completed so rapidly and the oil flame seems to glaze the surface, to put a protecting film on the surface of the refractory, thus giving it longer life than can be obtained when gas is used.

Combustion Chamber Design

Present day progress is leading to smaller and smaller combustion chambers. It is necessary that we should cut down this space, and as combustion engineers, it is this that we are trying to do. We have been able to develop as high as 550,000 Btu. per cu. ft. of combustion space per hour. This is the equivalent of burning more than 1,000 cu. ft. of city gas in a volume of 1 cu. ft. per hour.

At the present time we have a continuous carborizing furnace operating at 1,625 deg. F. with a thermal efficiency of 43 per cent. In this furnace the heating rate per square foot is about twice that normally considered safe practice. Future advance depends mainly upon the development of refractories which will stand up to this severe treatment. The objection has been raised that we should not cut down on the size of the combustion chamber that we should rather increase it to insure longer life in the refractory. We freely admit, that the refractory will give much more satisfactory service under those conditions. We could probably use the cheapest grade of fire brick if we built the combustion chamber large enough. However, to do so would be to take a step backward rather than forward. Naturally, better and higher priced refractories can be used in construction of this type.

*Abstracts from paper delivered at spring meeting, American Refractories Institute, Atlantic City, May 18, 1927.

Furnace Atmosphere

The fact that the furnace atmosphere has an important bearing on the life of the lining is well understood. The fact that silicon carbide must be used at high-temperatures in a reducing atmosphere is of course well known. This condition is easily handled in many furnaces. However, the problem of finding a refractory material, which is equally satisfactory, which can be used in furnaces in which an oxidizing atmosphere must be maintained still remains. The fact that metallic vapors from the work in the furnace decrease the useful life of certain refractories when used in the lining is also well known. The part these factors play and the troubles they introduce may be best discussed in connection with concrete examples.

Continuous Carbonizing Furnace

First let us consider a furnace of the continuous underfired carburizing type. The particular installation that I have in mind is of the semi-muffle type. The work chamber is 30 ft. long, 24 in. high and 4 ft. wide inside dimensions. The furnace is underfired that is, there are two passages running lengthwise through the furnace in which combustion takes place. The firing equipment consists of four oil burners. One firing into each end of each passageway making four in all. Above the hearth at the outlet end is a muffle 13½ ft. long. The flue gases in the fore part of the furnace pass from the combustion chamber up the sides over the work and out at the top. The flue gases at the other end pass around the muffle and out the top. As the work, in metal boxes passes through the fore part of the furnace it comes up to temperatures, then passes through the muffle at constant temperature and is finally discharged at the back. In the original installation the automatic temperature control depended on the temperature of the furnace at the center of the muffle.

That is when the temperature there went too high, the oil was shut off and vice versa. All went well for a time then the skidrails began to sag. Particularly in the fore part of the furnace. Upon examination it was discovered that the piers underneath had failed. It was observed that occasionally one of the oil burners would become clogged. The temperature in the muffle would then drop and the operator would manually operate the oil valve in order to get the line opened up and to bring the temperature of the furnace rapidly back to the desired temperature; he would force the oil combustion for a while. This would expose the bricks in the pier and side walls to a higher temperature than they could withstand, and caused the failure. The remedy was quite simple. The automatic control in the muffle was retained; however, an auxiliary control was added. Thermocouples were placed in the side walls. Thus, whenever the temperature of the side walls reached the maximum safe temperature the oil supply was shut off even though the temperature in the muffle had not reached the operating maximum. As long as these temperature controls are working it is impossible for the operator to force the furnace or to expose any part to greater than the safe working temperature.

Enameling Furnace

In the consideration of an enameling furnace we meet further difficulties. As an example, we have a furnace which has a work chamber large enough to

take a single bathtub. It is about 6½ ft. wide at the hearth inside, and about 8 ft. wide at the top, inside. The hearth is supported by nine piers. The furnace is equipped with nine oil burners cross firing between these piers. The products of combustion pass under the hearth, up the sides, over the work and out the top. Since this is an enameling furnace and the enamel contains lead oxide it is necessary to maintain a slightly oxidizing atmosphere in the furnace. In the original installation the piers and hearth were both constructed of silicon carbide brick and tile. After it had been in operation awhile the boys were able to go in and shovel out the refractory. It had completely gone to pieces. The operating temperature of such a furnace is between 1,700 to 2,200 deg. F.

With a given flue gas composition silicon carbide may stand up well at lower temperatures and also at higher temperatures, but rapidly go to pieces in this range 1,700 to 2,200 deg. F. Again it seems to stand up better when oil is used even in the range. The question arises what refractory can be used in constructing the piers in furnaces in which an oxidizing atmosphere must be maintained, in constructing piers that must withstand temperatures as high as 2,500 deg. F. The refractory must have strength, resistance to heat, and to oxidation at these temperatures.

We believe that tile so constructed will retain their coefficient of thermal conductivity and at the same time be protected from the oxidizing atmosphere and the corrosive effects of the enamel by the clay coating.

A Possible Solution

We formerly lined our crucible brass melting furnaces with a rammed silicon carbide lining. One of the furnaces was used in melting a copper alloy, half copper, and half lead. It was discovered that if lead were first melted in the crucible thus exposing the lining to the action of these lead vapors that the furnace could be used then for melting the copper-lead mixture and that the lining would last many times as long as a lining which had not had this treatment. That is, the lead melted and evaporated from the crucible seemed to put a protecting surface on the silicon carbide lining which protected it from further action. We believe that brick makers will be able to put a similar glaze on these refractory bricks which will protect and lengthen their life. Possibly the thin veneer already mentioned will solve the problem.

Possibly we will have to develop new, more suitable combinations. We have found a material in which a chrome base is used which on the fore hearth of our continuous billet heating furnaces stands the gaff. The temperature here is 2,300 deg. F. We have made some preliminary tests, on special brick that look good. However, these mixtures are expensive and cost is a vital factor. In one of our recent jobs, 300,000 refractory and insulating brick were used. Small variations in the cost of brick become a real factor when multiplied by 300,000 on a single job.

Brass Melting

The brass melting furnace offers new problems. In the small crucible furnace a lining is needed which will better withstand the temperature changes, that occur with intermittent use, that is, for operation on eight or nine hours per day. Linings have been developed which have a life of 4,000, 5,000, 6,000, and 7,000 heats in furnaces which are operated continuously. The

life of linings in the intermittently operated furnace can certainly be improved. One of the earliest crucible brass melting furnaces that we built had a very high thermal efficiency. It was so good that the first hour of operation melted down not only the metal in the crucible, but also the crucible, the pedestal, and the lining of the furnace wall. The whole then went down together and about all that remained was the outside shell. The thermal efficiency of the crucible furnaces melting copper, and brass is about 10 per cent. This is not high enough and the problem becomes a refractories problem. A problem of finding materials of which to build the crucibles, pedestal and linings.

Efficiencies of 8, 10, 12 and sometimes 15 per cent for gas and of 5, 6, and 8 per cent for oil, are being obtained in general practice at the present time. If we can find a refractory which will stand up, in order that we may fire indirectly, obtaining thermal efficiencies of 20, 25 or possibly 30 per cent we will have made a real advance over present practice.

Summary

Specific and Immediate Refractory

Requirements—

First—A refractory material with considerable strength which will withstand temperatures up to 2,500, 2,600 and 2,700 deg. F., which can be used in oxidizing atmospheres and another in reducing atmospheres, these to be used in constructing the piers of the furnace.

Second—A material with high thermal conductivity to be used in the hearth which will be resistant to oxidizing atmospheres. If we cannot find a material that will not be harmed by metallic vapors such as are present in enameling furnaces and brass melting furnaces then we must find a means of protecting the refractory.

Third—We must find an insulating material which will withstand temperatures up to 2,600 and 2,700 deg; of which, we can construct doors, and side walls.

However, the solution of these particular refractory troubles is not the main problem now confronting the furnace and refractory manufacturers. As soon as these problems are solved the equipment will advance accordingly and we will both find ourselves surrounded by a new and more difficult set of problems.

The real solution is a means of co-ordinating the combined facilities and experiences of the refractory and furnace manufacturer, and establishing such co-ordination on a permanent business basis.

We appreciate very much this opportunity you have afforded us of presenting some of our problems, experiences and view points.

We feel confident that the American Refractories Institute is best qualified and is found to play an important part in the organization of the forces which will carry the developments continuously forward.

Gas Replaces Forge of the Ancients in 1927 Swordmaking

The sword of Damascus, the acme of the ancient craft of swordmaking, is now equalled by modern swordmaking practice in a plant in Cincinnati, O.,

according to A. M. Forkner, of the Columbia Gas and Electric Company. The forge of the ancients has also given away to modern gas-fired furnaces that turn out swords as fine as those that the old artisans hammered out with fond indulgence.

"While swordmaking is still a handicraft, modern machinery is able to make the weapons just as well and in much larger numbers," says Mr. Forkner. "Mechanical hammers pound out the steel bars and modern heat-treating processes insure a well-tempered blade quality. The company has used gas for 15 years.

"The ancient code is still carried on in modern processes. A good sword should be elastic, to stand bending or a heavy blow without breaking; yet it must be stiff enough to yield a powerful thrust. It must be as light as is consistent with strength."

Balance is also extremely necessary, Mr. Forkner claims.

"By using gas as fuel for their metal melting pots," he continues, "the company secures benefits and advantages of heat centralization, cleanliness, and convenience."

Manganese Production Decreases in 1926

The shipments of high-grade manganese ore, containing 35 per cent or more of manganese, from the mines in the United States in 1926 were slightly less than half as large as similar shipments in 1925, according to the United States Bureau of Mines, Department of Commerce. The shipments in 1926 by 45 producers amounted to 46,258 long tons as compared with 98,324 long tons by 42 producers in 1925. This decrease was due to the falling off of the shipments from Montana.

The domestic production of metallurgical ore in 1926 was 26,530 tons; that of chemical ore, 19,728 tons. Montana was the largest shipper with 5,713 tons of metallurgical ore and 17,904 tons of chemical ore. The largest individual shipper of metallurgical ore was the Crescent Mine in the Olympic Mountain Region, Clallam County, Washington, from which the shipments for the year were 3,162 tons. The mine was operated by lessees and reverted to the owners in July, and thereafter to the close of the year no ore was shipped.

There was no output of high-grade ore from Leadville, Colo., during the year. Some of the producers claim they can not operate commercially under present prices. The production of Colorado during the last four years has been—1923, 2,278 tons; 1924, 5,338 tons; 1925, 743 tons, and in 1926 no production was reported. The price of manganese during the period mentioned has been relatively constant.

There was a material decrease in the shipments of high-grade ore from Arkansas. In 1925, this state produced 3,517 tons and in 1926, 2,450 tons. During the year two properties were equipped for the production of low-grade ores, ranging from 20 to 30 per cent manganese. For the first time Idaho shipped manganese ore. During the year 1926, 800 tons of metallurgical ore and 30 tons of chemical ore were shipped.

The shipments of domestic ore containing 10 to 35 per cent manganese (ferruginous manganese ore) increased from 267,252 tons, valued at \$915,316, in 1925 to 364,312 tons, valued at \$1,179,429, in 1926.

The Brick Mason's Fire Brick Guide

The old policy of buying a carload of fire clay brick and using it for all purposes around a steel plant has passed. The brick mason today buys a specific brick, as to burn and grind, which he believes to be the one best suited for each individual use in his plant.

There are three general characteristics that have the greatest influence on brick under heat, chemical analysis, grind and burn.

The proper analysis of clay in making fire brick is largely a matter of opinion and use. If first quality fire brick is purchased at all times, not much trouble will arise from this source.

By grind is meant the comparative degree of coarseness or fineness of the particles of the conglomerate mass entering into the brick. There are three grinds used in the manufacture of brick, coarse, medium and fine. The difference in degrees of the relative refractoriness of these different grinds is very slight when the same clays are used.

The coarse grind produces what is considered a porous and open structure brick. By reducing the grind to fine the pore space is less, which results in a more dense brick structure. The porous, open structure brick best withstands thermal shocks with the smallest degree of spalling. This type brick is vulnerable in that it is open to clay and clay vapor penetration. The finer ground and dense brick is more given to spalling, but much more resistant to slag penetration.

Some recent research and plant tests have shown that the strength, refractoriness and spalling of brick

can be considerably bettered by a right proportioning of the three grinds. That is a clay brick made from a mix of coarse, medium and fine grind will produce a better brick. The total porosity is not reduced or changed very much. The advantage appears to be in the fact that the total pore space has been thus more finely divided and more evenly scattered through the brick.

There are three different "burns" given to fire brick by the manufacturer in his kilns, hard, medium and soft. Each particular "burn" giving the brick certain characteristics which makes it most suited for some particular location in a furnace. The "burn" of brick can be determined when examining the brick by its ring, its color and its size. By ring is meant the sound obtained by striking one brick against another; a dull

thud indicates a soft burn, the sound becoming more or less metallic and bell like as hard burn is approached.

Another characteristic of fire brick is that the harder the burn the smaller the size as caused by the greater burning shrinkage. Hard burned brick generally have the burning shrinkage reduced to a minimum, which in many installations is a necessary requirement. Soft burned brick in such jobs, may show considerable burning shrinkage at high operating temperature, and thus weaken the brick structure and probably cause actual wall failure.

The following table gives the generally accepted burns and grinds specified by leading brick masons for steel mill use:

The pleasing reception that had attended the insertion in *The Blast Furnace and Steel Plant* of a section devoted to refractories has been most encouraging to the publishers. Starting in February this section has been in each issue and will hereafter be assured a prominent position in the magazine. In forthcoming issues photographs of prominent mason superintendents will appear.

TYPE OF FURNACE	BURN	GRIND
Blast furnace top	Hard	Fine
Blast furnace inwall	Medium to hard	Medium
Blast furnace hearth and bosh	Medium	Coarse
Stove	Medium	Medium
Open-hearth checker brick	Medium	Medium to fine
Soaking pit covers	Medium	Medium to coarse
Soaking pit side walls	Medium	Medium
Soaking pit above slag line	Medium	Medium
Steel plant flues and underground work	Hard	Medium
Bee hive coke ovens	Medium	Medium
By-product coke ovens	Hard	Fine
Boiler settings	Medium	Medium
Malleable iron furnace	Light	Coarse
Malleable furnace side wall	Medium	Medium
Electric furnaces	Medium	Medium to fine

Thermal Conductivity of Refractories

By ALEXANDER WISHNEVSKY*

THE thermal conductivity of refractory material is equal in importance to its refractoriness. A refractory material might be perfect in its ability to withstand extremely high temperatures under load with no expansion, slagging or spalling, and yet, if this material offered little resistance to the flow of heat, it would be worthless for lining generators and furnaces.

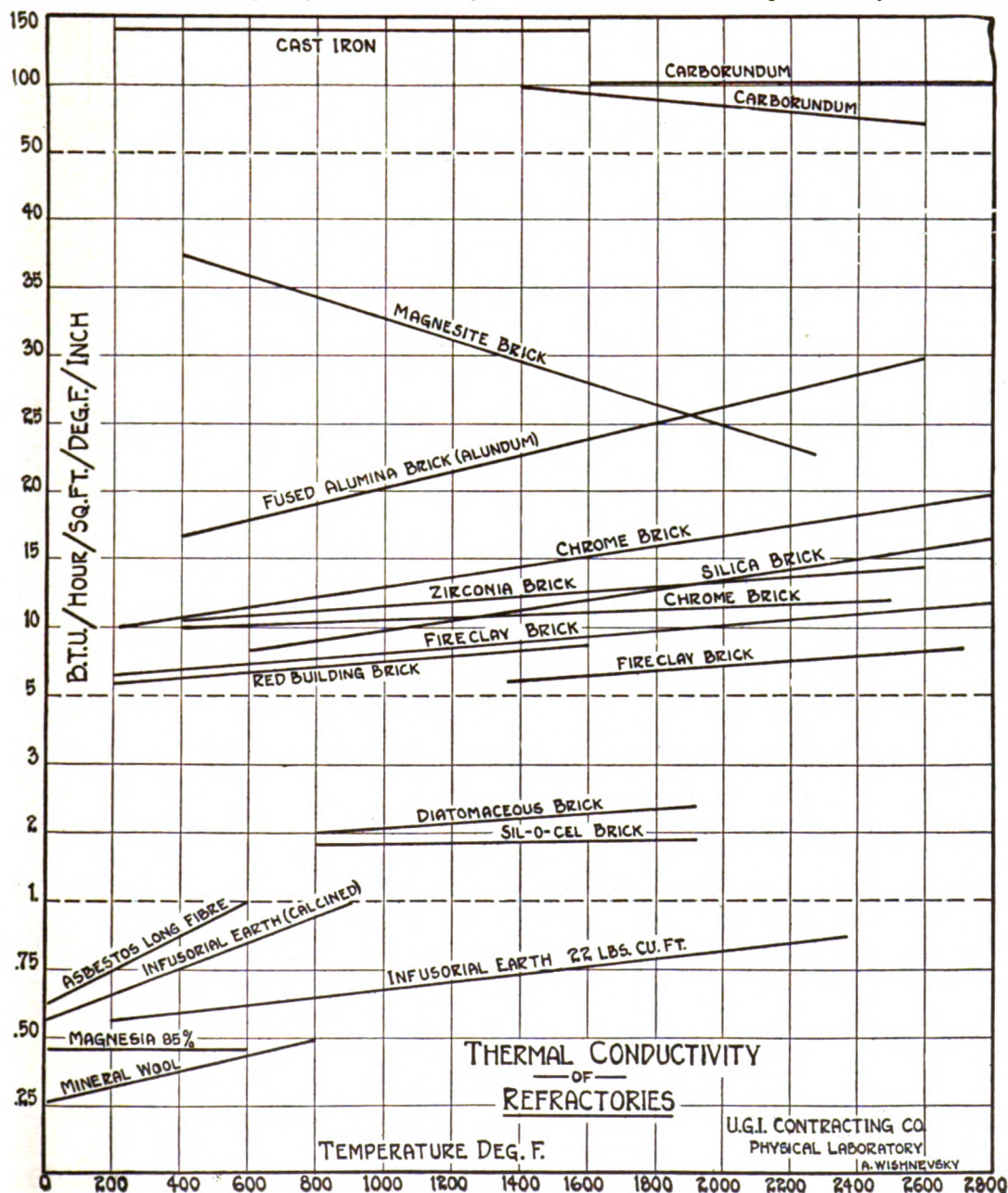
Besides obtaining authentic information on heat conductivity, it is always necessary to know the physical behavior of the material at higher temperatures, such as: degree of shrinkage or expansion, porosity and permeability to gases. In other words the existing data on heat conductivity cannot take care of every individual case with a high degree of precision, and this is particularly true in regard to the better

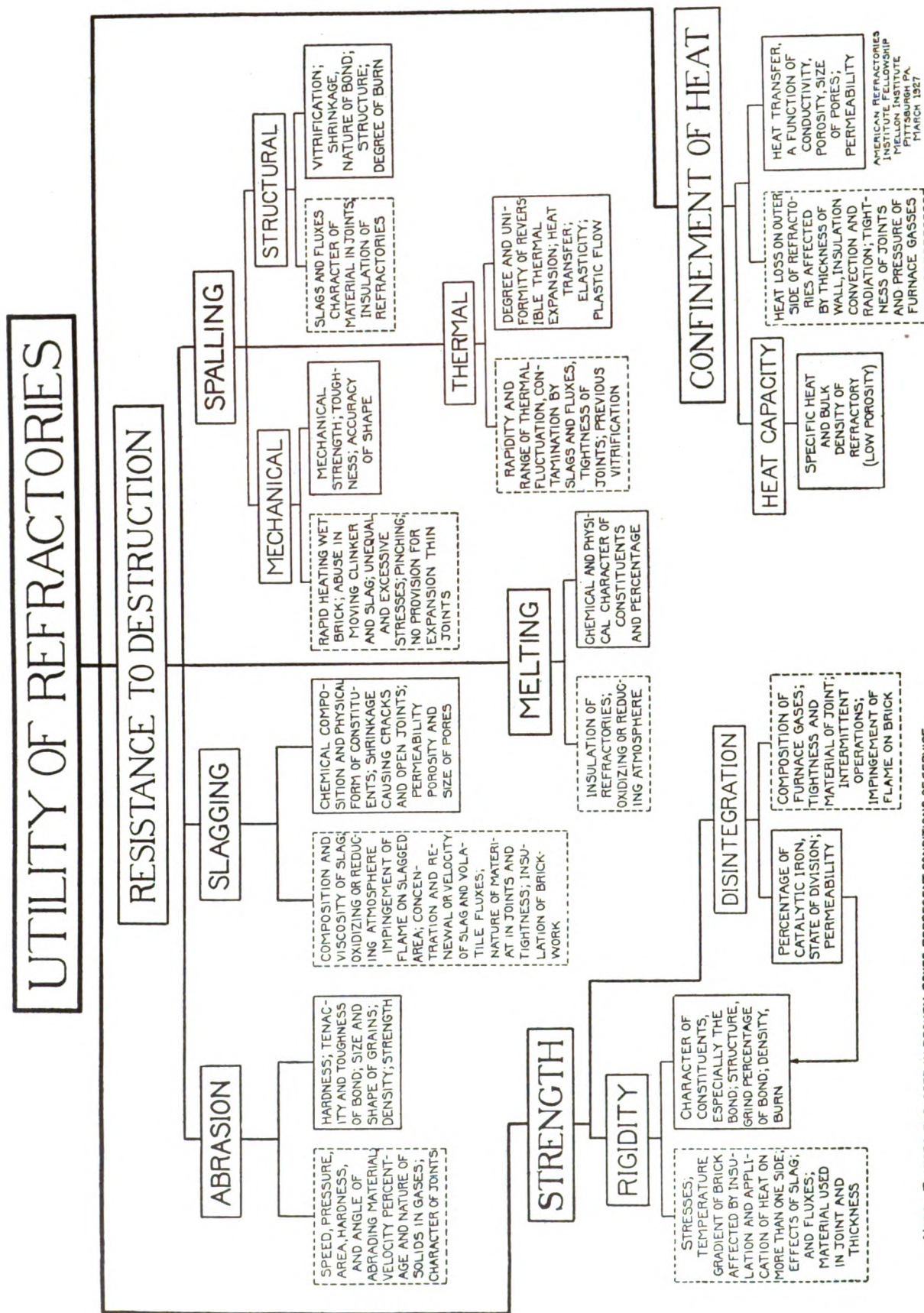
heat conductors. However, for all practical purposes and approximate estimates, the chart offered herewith will be of assistance to all interested in heat transfer problems. It gives the thermal conductivities of insulating materials and refractories in Btu. per square foot, per hour, per inch for various temperatures. The quantity of heat passing for other temperature heads and thicknesses will vary directly as the temperature head and inversely as the thickness.

In compiling the chart the results obtained by The U. G. I. Contracting Company's Physical Laboratory were correlated with the results published by various other investigators, and the results plotted as shown.

The conductivities fall into three main groups, and in order to plot them all on one chart, the different scales are separated by horizontal dotted lines.

*The U. G. I. Contracting Company Physical Laboratory.





REFRACTORIES UTILITY CHART

Most of the factors of service and properties of refractories given in this chart are interdependent and are greatly affected in degree by the functions of temperature and time. The factors in the chart are believed to cover the more common conditions encountered and naturally vary in degree depending upon the type of service in question.

WITH THE EQUIPMENT MANUFACTURERS

Motor with Roller Bearings

One of the General Electric's new standardized mill type motors—Hyatt roller bearing equipped—will be on display at the booth of the Hyatt Roller Bearing Company during the Iron and Steel Exposition. The new line of motors of which this one is representative, meets A. I. & S. E. E. requirements, and provides for the use of anti-friction bearings.

The Hyatt Roller Bearing Company is well represented in the electric motor application. Three other manufacturers—Crocker-Wheeler, Shaw, and Westinghouse—have designed for Hyatt bearings as special or standard equipment. There are more mill and crane type motors with Hyatt roller bearings than any other type of anti-friction bearing.

The Hyatt railway journal box that is so much discussed today, will also be on exhibition. It represents several years of experimentation and actual service. A similar Hyatt equipped box has run over 350,000 miles on the Chicago, Milwaukee and St. Paul railroad, without shopping for bearing repair of any description. This type of box is going into service on 120 North Western passenger coaches, and several other roads have adopted it for suburban and through trains.

Experienced bearing engineers will be in charge of the Hyatt booth to explain the many allied applications which will be shown.

Third Oil-Electric for Chicago and North Western Railway Leaves Schenectady

Traveling under its own power, the third oil-electric locomotive for service on the Chicago and North Western Railway left the assembling works of the American Locomotive Company, Schenectady, April 17, for delivery to the railroad at Chicago. The locomotive, running only in daylight, will take approximately one week for the trip.

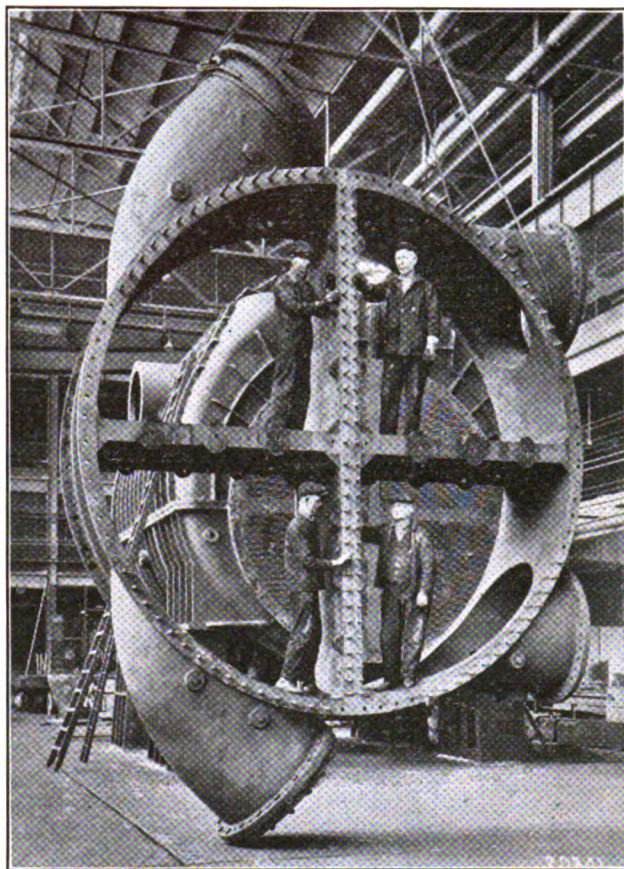
The 820-mile run will be made over the New York Central lines from Schenectady to Niagara Falls and over the tracks of the Michigan Central Railway from Niagara Falls, through Southern Canada and Detroit, to Chicago. Night stops along the way will afford opportunity for inspection of the new type of rail motive power by the public.

The oil-electric locomotive, of the 60-ton size, equipped itself with enough fuel oil and water at Schenectady to last the entire trip. On a run over the same route last fall an oil-electric of the same size, on delivery to the Chicago and North Western, consumed 218 gallons of fuel oil, at a cost of approximately \$11.50 for the entire run. The average cost of fuel was one and one-half cents a mile.

The daily average fuel cost of the oil-electric at Chicago is given by the Chicago and North Western officials as \$6.20, as against \$20.15 for a steam-driven locomotive doing the same work.

Large Condenser Almost Completed

The inlet water chamber of a 62,500 sq. ft. surface condenser for use with one of the large turbines is in the final stage of completion at the South Philadelphia Works of the Westinghouse Electric and Manufacturing Company. The monstrous casting weighs 36,000 lb., and will be bolted to a main condenser. This condenser is a colossal piece of equipment nearly 24 ft. high and it weighs 600,000 lb.



The condenser is fitted with a total of 10,840 single tube sections; the tube being made of Admiralty metal, 1 in. in diameter and 22 ft. 3 in. each in length. The total length of these copper tubes is approximately 46 statute miles, and when in operation with both of its circulating pumps, each passing 36,250 gallons per minute, the condenser will handle 104,500,000 gallons of water per day. Two condensers of this type are being completed at the Westinghouse Works for the Duquesne Light Company to be installed at the Colfax Station in Pittsburgh.

A New "Buffalo" Horizontal Punch

The Buffalo Forge Company, N. Y., is adding to its line of "Armor-Plate" punches, shears and bar cutters a horizontal punch. This new punch is designed for convenience in punching flanged pieces, boiler heads, curved angles, beams, channels and other shapes.

Johns-Manville Radiator Control Valve

Referring to the cross-section sketch A and B designate the disc and seat of the valve and C is the sleeve with a slot, D, in it.

When the spindle is raised, the slot D is gradually exposed, allowing an increasing amount of steam to flow through it until it has reached a certain point, after which the entire seat is exposed, allowing a full opening of the valve and the maximum amount of steam to flow through it.

It is important to note here that the mixture of steam and air has a temperature lower than the steam supplied, and this temperature is dependent upon the quantity of steam admitted through the nozzle E.

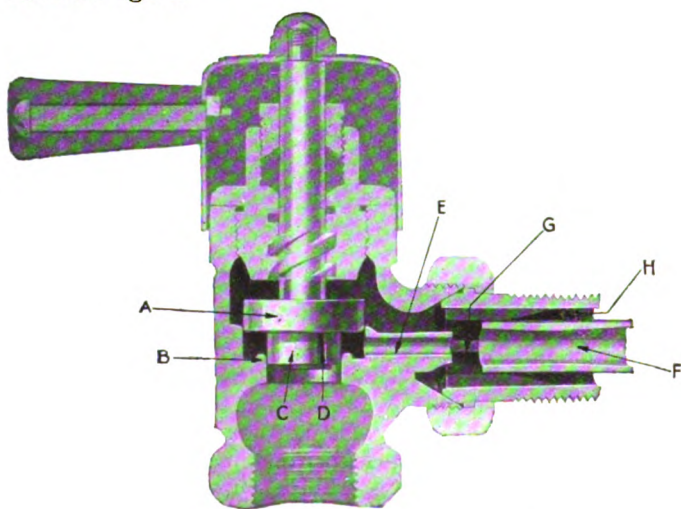
When the valve is wide open, i.e., after the disc or piston A has been raised entirely clear of the cylinder through which it slides, steam is permitted to enter the radiator through the large port over the nozzle E, as well as through the nozzle E.

This provides a means of filling the radiator with steam at full pressure at any time required, as, for example, quick heating up in the morning or during extremely cold weather.

The mixture of steam and air flowing into the radiator through the venturi tube F, drives along through the upper connecting nipples of the radiator, passes down through the sections of the radiator, and

Before the slot D is fully exposed, the steam passes through it into the nozzle E and through the venturi tube F.

This flow creates a vacuum at G. This vacuum causes a flow of the heating medium (air and steam) from the radiator back through H to G where, mixing with the incoming steam, it is carried back into the radiator again.

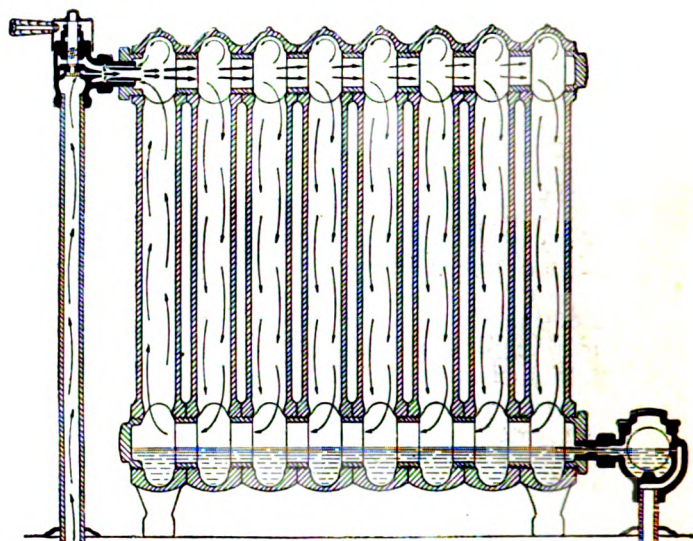


back through the lower connecting radiator nipples, finally up through the first section and back to the inlet connection, where it is again drawn into the valve around the venturi tube at H and recirculated.

Note—The above description applies when the valve is connected to the top of the usual hot water type radiator now generally used in steam heating systems. When steam pattern radiators are used, it can be connected with the bottom of the radiator.

The advantages of heating with hot water are well known, and the desirability of producing hot water effects by steam will be readily appreciated.

Briefly, the advantage of a hot water system, or a steam heating system equipped with the Johns-Manville radiator control valve, is that a radiator can be heated to any desired temperature under 212 deg. F., depending upon weather conditions. A mild and uniform warmth is conceded to be more healthful than high temperature heating.



With ordinary steam heating systems, radiators are either cold or have all or part of their surface heated to full steam temperature. Full steam temperature is undesirable not only on account of the reasons given above, but because heating at full steam temperature is not as economical as heating with lower temperatures.

When a radiator is heated to high temperatures, there is a rise of highly heated air to the ceiling and a flow of cold air along the floor to the radiator, resulting in uneven distribution of room temperature, the heat being at the top of the room instead of nearer the floor where it is required.

With lower radiator temperatures, the air is not so highly heated and therefore becomes more evenly distributed throughout the entire room.

Economy, therefore, is afforded by the latter method because there is not so much heat loss on the sides and ceiling of the room with which the hot air comes in contact, and not so much direct radiation through the windows when radiators are placed underneath them.

Gun for Refractory Cements

Botfield Refractories Company, Philadelphia, has developed a method of maintenance that makes it easy to keep refractory construction in good condition through periodic and systematic maintenance.

In this method of refractory maintenance, three major elements are employed. They are The Adamant Gun, Adachrome (a chemically-neutral refractory material), and Adamant Fire Brick Cement.

Weighing less than 4 lb. The Adamant Gun requires only one man for operation. It uses air or steam at 50 lb. pressure or more. As air is more satisfactory in results, its use is recommended wherever possible.

SAFETY FIRST IN THE STEEL PLANT

Section Devoted to the Interest of the Safety Movement

There's No Good Luck Charm Against Accidents Except Common Sense Plus Carefulness

By J. F. Stephens, B. & O. Magazine

There are but three causes that contribute to accidents, namely:

- 1—Acts of God (weather conditions, slides, etc.)
- 2—Hazardous property conditions.
- 3—Human failure.

We must disregard the first cause which, incidentally, does not produce 1 per cent of our accidents, because we have no control over it.

The second, property conditions is yearly becoming less of a problem, because our managers have used their common sense by generally eliminating property hazards. They realize that it is usually cheaper to remove those hazards than to pay for the injuries they may cause.

In considering the third cause, human failure, let us remember that the greatest beneficiary of safety is the employee. Upon him is imposed all the suffering, all the misery and all the privation resulting from injury. Yet more than 90 per cent of all employees' injuries are due to human negligence in some form—to someone's failure to give sufficient thought to safety.

Meetings

June 15—Southern States Safety Conference, Birmingham, Ala., Perkins J. Prewitt, manager, Birmingham Safety Council, 1916 Age-Herald Building, Birmingham, Ala.

June 14—Third Annual Fox River Valley Safety Conference, Sheboygan, Wis. G. E. Burns, National Safety Council, Chicago.

June 22-23—Lake Superior Mining Section, Annual Safety Council, Annual Conference, Duluth, Minn. A. A. Bawden, Pickands-Mather & Company, Ironwood, Mich.

September 26-October 1—National Safety Council, Sixteenth Annual Safety Congress, Hotel Stevens, Chicago. W. H. Cameron, managing director, National Safety Council, 108 East Ohio Street, Chicago.

October 3-7—American Electric Railway Association, Annual Convention, Public Auditorium, Cleveland, Ohio. J. W. Welsh, executive secretary, 292 Madison Avenue, New York City.

October 24-28—Fourth Annual Pacific Safety Conference, Los Angeles, Cal. W. Dean Keefer, National Safety Council, Chicago.

Goggles Save Eyes

The annual safety report of the Colorado Fuel & Iron Company, fuel department issued in January, 1927, has this item in part: "Goggles have proven their worth; eye injuries have been reduced 60 per cent since their installation. Some of the 26 eye injuries that occurred in 1926, could have been avoided if the injured men had not tried to get along without their goggles. Men who attempt to beat the goggle rule are only hurting themselves. It was for their own protection that goggles were installed and it is for their protection that we are insisting on their use. The large reduction in eye injuries, dating from the time goggles were first used, convinces us that practically all eye injuries can be eliminated, and each eye injury in 1927 will be carefully investigated." — From National Safety Council Bulletin.

Supervision and Safety

Experience has demonstrated that there is one fundamental principle underlying all effective accident prevention activities, namely, that safety is a definite and integral part of supervision.

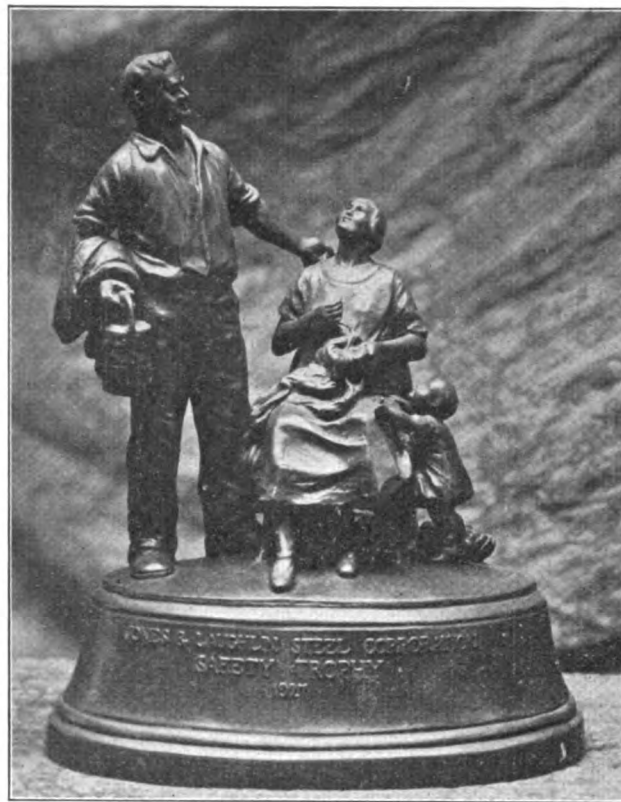
The time is fast approaching when supervision efficiency will not be judged en-

tirely by production records, but also by accident prevention records.

A reduction of accidents is not accomplished by the discharge of careless men, necessitating the employment of new untrained men who may be equally careless. It is dependent upon the ability of the organization to obtain the proper spirit of co-operation from its existing force.

This is efficient supervision whether applied by the highest operating official or the lowest paid subforeman. —Metropolitan Life Insurance Company.

The National Safety Council, 108 East Ohio Street, Chicago, has announced a poster competition for accident prevention drawings. First, second and third prizes of \$500, \$300 and \$200 respectively will be given.



The 1927 Safety Trophy of the Jones & Laughlin Steel Corporation, which is being competed for by the South Side Works, North Side Works and Aliquippa Works.



L. S. Longenecker, until recently Pittsburgh sales representative for the Vitrefrax Company of California will act in a similar capacity for the Chas. Taylor Sons Company, manufacturers of refractories and fire brick, Cincinnati, O. He will retain his office at 409 Bessemer Building, Pittsburgh, Pa., and will have charge of sales in Western Pennsylvania, Eastern Ohio and West Virginia. Mr. Longenecker graduated from the Pennsylvania State College in the class of 1921. He then entered the employ of the Jones and Laughlin Steel Company as refractory engineer of the South Side plant and for three years closely followed all experiments in connection with refractories. While associated with the Vitrefrax Company, Mr. Longenecker's activities necessitated a knowledge of the application and behavior of superrefractories.



At the meeting of the board of directors of the General Electric Company, April 29 at Bloomfield, N. J., where the board met following the practice of inspecting from time to time the different plants of the company, Clarence M. Woolley, chairman of the board of the American Radiator Company, was elected a member of the board of directors. Charles W. Appleton of the law department was elected a vice president in charge of general relations with public utilities.

The annual meeting of the Pennsylvania Engineering Works was held May 16, 1927 and W. H. Lewis was re-elected president, W. S. Wheeler, vice president and treasurer and S. B. Cleal, secretary.

S. E. Conybeare, advertising manager of the Armstrong Cork Company of Lancaster, Pa., and president of the Association of National Advertisers, has

been elected a member of the board of directors of the Audit Bureau of Circulations. He will fill out the unexpired term of B. H. Bramble.

Dr. Duncan Allison, Welland, Ont., has been elected a director of Barbon Alloys Steels, Ltd. He succeeds W. W. McMaster of Detroit.

Elmore L. Ross has joined the Arch Machinery Company, Pittsburgh, the successor of Manning, Maxwell & Moore, Inc., with whom he formerly was associated.

F. H. Babcock, of the central station department, General Electric Company, has been chosen assistant to Charles W. Appleton. Mr. Appleton was recently elected vice president in charge of general relations with public utilities.

George H. Charls, formerly president and general manager of the United Alloy Steel Corporation, Canton, Ohio, has been elected president and treasurer of the Hiner Structural Steel Company of that city.

Henry C. Graham, in charge of the Upson Works of the Bourne-Fuller Company, Cleveland, has resigned. He was with the Upson Nut Company for about 16 years prior to its absorption by Bourne-Fuller Company in 1912.

Frederick C. Fairholme, managing director of Thomas Firth & Sons, Ltd., Sheffield, England and J. Worthley Fawcett, works manager, recently arrived in this country.

F. S. Jones, district sales agent at Oklahoma City, Okla., for the steel division of Colorado Fuel & Iron Company, Denver, has been made assistant manager of sales, with headquarters at Denver.

J. de N. Macomb, for many years railroad construction engineer, has been appointed assistant to the vice president in charge of railroad sales of the Inland Steel Company, Chicago.



C. B. Woodworth has been chosen manager of the western division of the Vanadium Corporation of America with headquarters in the Straus Building, Chicago.

* * *

Robert M. Crawford, formerly with The McAlenan Corporation of Pittsburgh, has severed his connection and has opened offices in the Commonwealth Building, Pittsburgh, where he will conduct a chemical and industrial engineering business for his own account. This business will include engineering service on problems pertaining to low temperature carbonization of coal.

* * *

H. C. Thomas has just been appointed assistant general manager of the merchandising department of the Westinghouse Electric & Mfg. Company. He was formerly assistant to the manager of the merchandising department.

* * *

Charles A. Fisher, vice president in charge of finance, was elected president of the Jones & Laughlin Steel Corporation at a recent meeting of stockholders. Mr. Fisher fills the vacancy caused by the death of William L. Jones. He has been vice president since 1923. B. F. Jones III, a grandson of the late B. F. Jones was chosen vice president and secretary. T. M. Girdler, vice president in charge of operations is now a member of the executive committee.

* * *

Ross L. McLellan, formerly managing director of Cia. Westinghouse Electric International, S. A., has been appointed general manager of the Westinghouse International Company with headquarters in New York. Mr. McLellan, whose appointment was effective April 1, arrived in New York recently from Buenos Aires and immediately assumed his new position.

* * *

The Ohio Electric & Controller Company, Cleveland, Ohio, announce the appointment of Mr. Wm. G. Ellis, with offices in the Atlantic Building, Philadelphia, Pa., as their district sales manager, effective June 1, in charge of their motor and magnet sales.

Dwight W. Morrow, of J. P. Morgan & Company, and Victor M. Cutter, president of the United Fruit Company, were elected directors of the International General Electric Company at a meeting of the board on April 29. Gerard Swope, president of the General Electric Company, was elected chairman of the board, succeeding the late Anson W. Burchard; Clark H. Minor was re-elected president; Walter J. Edmonds, comptroller, was elected a new vice-president in charge of financial relations; and E. F. Colyer was named comptroller.

* * *

Paul Kline, for the past nine years chief chemist and metallurgist for the National Transit Pump & Machine Company, will leave for Pittsburgh to take a position as industrial engineer for the People's Natural Gas Company, of Pittsburgh.

* * *

Mr. J. W. Tomlinson, for the past seven years, chief chemist of the Trumbull Cliffs Furnace Company, plant at Warren, Ohio, has resigned and has accepted a position with the Chicago Chemical Company, Ill. He will be located in the Northeastern Ohio Territory.

* * *

Lewis E. Pierson, chairman of the American Exchange, Irving Trust Company, was elected president of the United States Chamber of Commerce at the termination of its fifteenth annual meeting here on May 5. Judge Edwin B. Parker, of Houston, Texas, and Washington, D. C. was named to fill a newly created position of chairman of the board of directors.

* * *

The Electric Controller & Mfg. Company of Cleveland, Ohio, announces the appointment of the firm of Mr. J. B. McCarthy and Mr. W. P. Robinson as representatives in Canada. Their offices are at 307 Reford Building, Toronto, Canada, and 808 Drummond Building, Montreal, Quebec, Canada. The Electric Controller & Mfg. Company also announces the appointment of the Petroleum Electric Company, 217 East Archer Street, Tulsa, Okla., as their representative in Oklahoma and the Pan Handle district of Texas.

NEWS OF THE PLANTS

The newly completed heat-treating department of the Canton Drop Forging & Mfg. Company of Canton, Ohio, is now in operation. Greater floor space has been given to this department in order to facilitate the handling of material and to reduce costs.

* * *

The Montreal Coke & Mfg. Company has contracted with the By-Product Coke Company of Canada, Ltd., Canadian subsidiary of the Koppers Company for the design and construction of a Becker Type By-Product Coke plant. The installation will consist of 59 Becker Type Combination Ovens, four Koppers Gas Producers, complete equipment for by-product recovery and a Koppers coke handling plant. This plant will have an annual carbonizing capacity of over 450,000 tons of coal. All of the gas from the plant will be distributed by the Montreal Light, Heat & Power Consolidated.

* * *

The Ford Motor Company, Detroit, has begun the erection of three 100-ton open-hearth furnaces. These, with those already in service, will make seven furnaces operated by the company. The present four furnaces are of the tilting type, but the new ones will be of the stationary type. The Ford Company is also building two soaking pits, in addition to the four now in use. The company's 12-in. spring mill is now being erected and will probably be ready for operation in the fall. The extensions to the company's rolling mill equipment, as announced some time ago, includes a 10-in. combination mill for rolling both steel and copper. The plans have been changed for this type of mill, which now will be a 10-in. combination merchant mill for rolling rod, bars and strip steel.

* * *

The Riverside works of the National Tube Company at Benwood, W. Va., again are idle after several months of part operation on experimental work.

* * *

The Simonds Saw & Tool Company, Fitchburg, Mass., has purchased the plants and business of the Abrasive Company, Philadelphia, manufacturer of "Borolon" wheels for grinding steel and metals of high tensile strength, and of "Electrolon" wheels for grinding cast iron, brass, bronze and metals of low tensile strength. The company, which also manufactures abrasive cloths and papers, will continue to sell its products through its present channels.

* * *

The Hamilton Coke & Iron Company has purchased the property of the Hamilton Furnace Company at Coke Otto, Hamilton, Ohio. The new company has been organized by the Koppers Construction Company, Pittsburgh and will operate the blast furnace and the new Koppers coke plant which is to be built at once. An agreement has been about concluded by the Koppers Company and the American Rolling Mill Company, Middletown, Ohio, under which the latter company will acquire a one-half interest in the Hamilton Coke & Iron Company, and

will take the furnace company's entire output of pig iron in the form of hot metal. Hamilton furnace, which was last active in 1923, has been for a number of years in the hands of the Hamilton Furnace Company, of which John A. Savage, Duluth, Minn., is president. It is 85 x 20 ft., was built in 1907-8, and remodeled in 1918. The by-product coke plant under construction consists of 45 Koppers ovens, and a contract has been made to supply the city of Hamilton with gas. Foundations are in for a second blast furnace, but there is no plan for its immediate construction.

* * *

The new ingot mold plant of the Shenango Penn Mold Company, Sharpsville, Pa., has been completed and recently made its first shipments of molds.

* * *

The Allis-Chalmers Mfg. Company, Milwaukee, has acquired the Pittsburgh Transformer Company of Pittsburgh. The purchase gives the Allis-Chalmers Company a Pittsburgh plant, as the Pittsburgh company is to be maintained and operated as a subsidiary. R. V. Bignay, president of the acquired company and principal owner, will remain as its president and directing head and will become a director of the parent company.

* * *

Massillon Power Shovel Company, Massillon, Ohio, has bought the power shovel division of Russell & Company and the plant and business of the Massillon Foundry & Machine Company, both of Massillon, Ohio.

* * *

The Pottstown Metal Products Company, Pottstown, Pa., has begun operations in its new plant. The plant, approximately 100 x 220 ft. and of steel and glass construction, is equipped for tank and steel plate work. The new plant lies between the tracks of the Pennsylvania and Reading Railroads.

* * *

The Interstate Iron & Steel Company, One hundred and eighteenth Street and Calumet River, Chicago, will build an open hearth furnace building, 129 x 145 ft., to cost \$120,000. F. Hoffman, 208 LaSalle Street, is architect.

* * *

The Williams Welding & Mfg. Company, recently organized, has started operations in the plant at one time occupied by the Hussey-Binns Shovel Works, and later by the Atlas Steel Corporation, Third Street, Charleroi, Pa. It is specializing in water-cooled door frames, ports, and other water-cooled equipment, and in addition, will do commercial welding.

The annual meeting and banquet of the Veterans Association of Farrel Foundry & Machine Company, Ansonia, Conn., was held in the Masonic Temple at Ansonia the afternoon of May 14. The Veterans Association consists of employees who have been with the Farrel concern for 25 years or more.

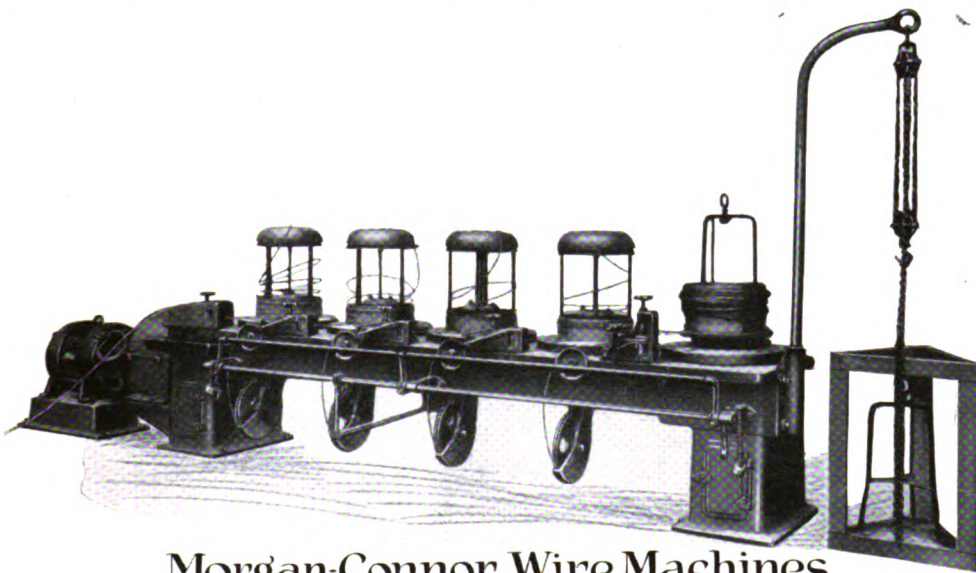
The Blast Furnace *(and)* Steel Plant

Member of the Audit
Bureau of Circulations

PITTSBURGH, PA., JUNE, 1927

Entered as second class mail matter at Pittsburgh,
Pa., under the act of Congress, March 3, 1879.

MORGAN WORCESTER ENGINEERS AND MANUFACTURERS



Morgan-Connor Wire Machines

offer these advantages

Safety

Flexibility

Low Upkeep

Oil-tight Transmission

Less Floor Space

One-way Trucking

No Pits

No Floor Reels

Direct Motor Start

No Lifting

Lower Tonnage Rates

*and
Higher Hourly Earnings*

MORGAN CONSTRUCTION CO.
WORCESTER, MASSACHUSETTS, U.S.A.

JUN 14 1927